4.3. Status and Trends of Habitat and Environmental for Tortoise Populations

4.3.1 Road Case Study

A case study in the western Mojave Desert provides an example of documenting changes in status of the environmental setting of the tortoise relative to a specific threat (roads) to tortoises and their habitat. This case study illustrates how a specific failure in Recovery Plan implementation results in direct impacts on tortoise habitat. To control vehicular access within all DWMAs, the Recovery Plan recommended to: 1) prohibit vehicles off roads; 2) restrict establishment of new roads; 3) implement closure to vehicular access with the exception of designated routes; and 4) implement emergency closures of dirt roads and routes as needed to reduce human access and disturbances in areas where human-caused mortality of tortoises is a problem. The Plan furthermore highlighted the need to halt unauthorized ORV use in the Fremont-Kramer DWMA (Table 4.3). Fig. 4.31 illustrates routes identified by BLM in the western Mojave critical habitat units in 1985-87. While innovations in mapping technology make it problematic to conduct a quantified comparison of routes identified in the mid-1980s to those identified more recently, Fig. 4.32 clearly shows that routes had not been reduced in the western Mojave Desert through 2001. Instead, routes are likely to have greatly increased during this time, with concomitant increases in public access, crushing, fires, and other potential impacts to the tortoise population (see next section).

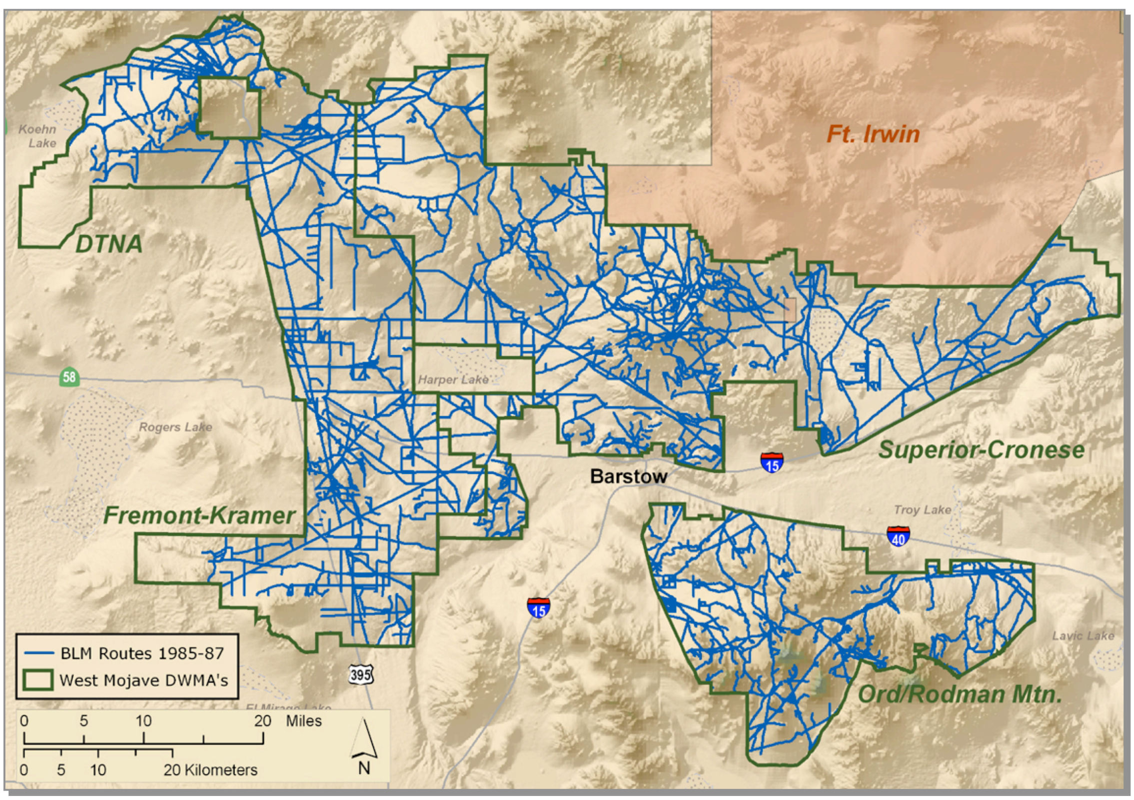


Fig. 4.31 Routes identified by BLM in western Mojave DWMAs in 1985-87.

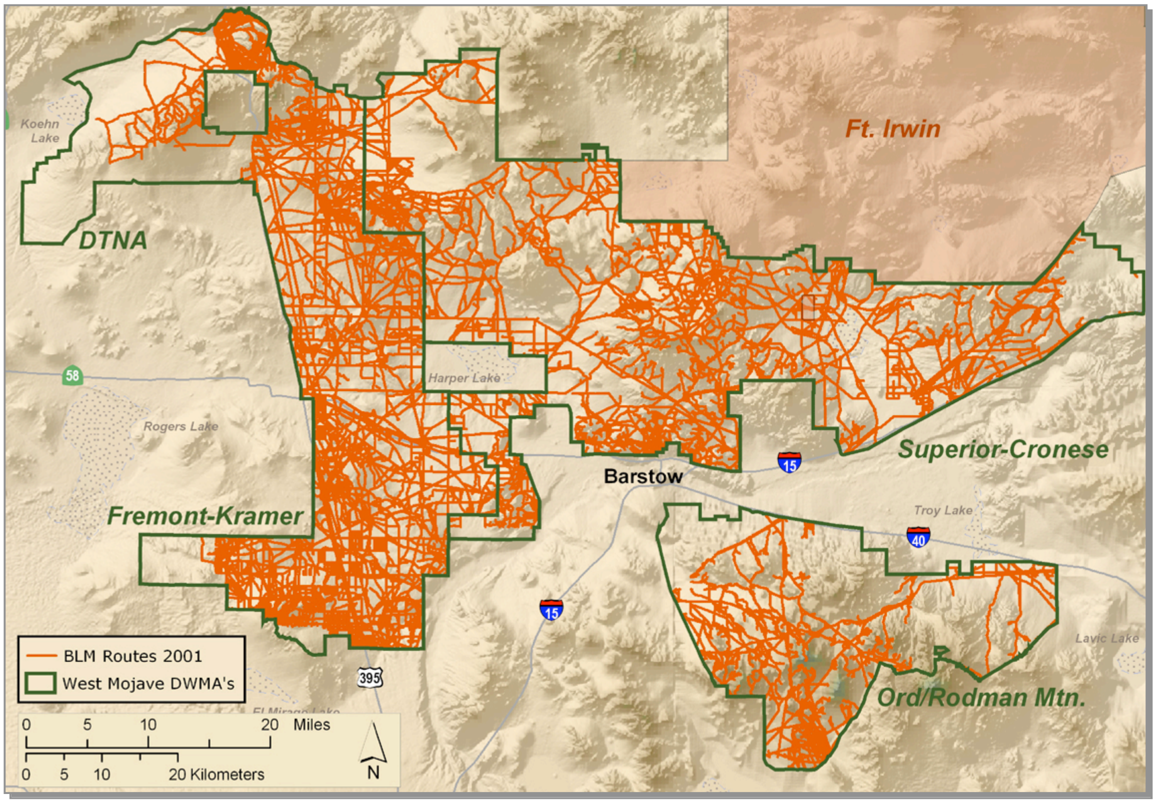


Fig. 4.32 Comparison of routes identified by BLM in western Mojave DWMAs in 1985-87 to those identified in 2001.

We recognize that we have made only a cursory analysis of habitat and environmental status and recovery plan implementation. A more detailed examination of agency actions may reveal a higher degree of implementation than revealed in Table XX. Our road case study does highlight, though, the insufficiency of not implementing all management actions relevant to a particular impact to tortoise populations and habitat. We hope that this summary provides a baseline from which to evaluate current and future management efforts. Managers should critically evaluate Table XX to confirm that recommendations shown to be at least partially implemented are, in fact, being *effectively* implemented, and actions that have not been implemented are initiated.

4.3.1.1 Recommendation

This type of analysis should be conducted for other specific threats to tortoise populations, as well as ecological variables that may also influence tortoise population status (e.g., rainfall, Fig. 4.33). Such analyses will provide managers and scientists with a comprehensive database of the current environmental setting under which tortoise recovery is taking place and will provide the basis for future hypothesis-based monitoring of tortoise populations relative to threat mitigation and environmental change.

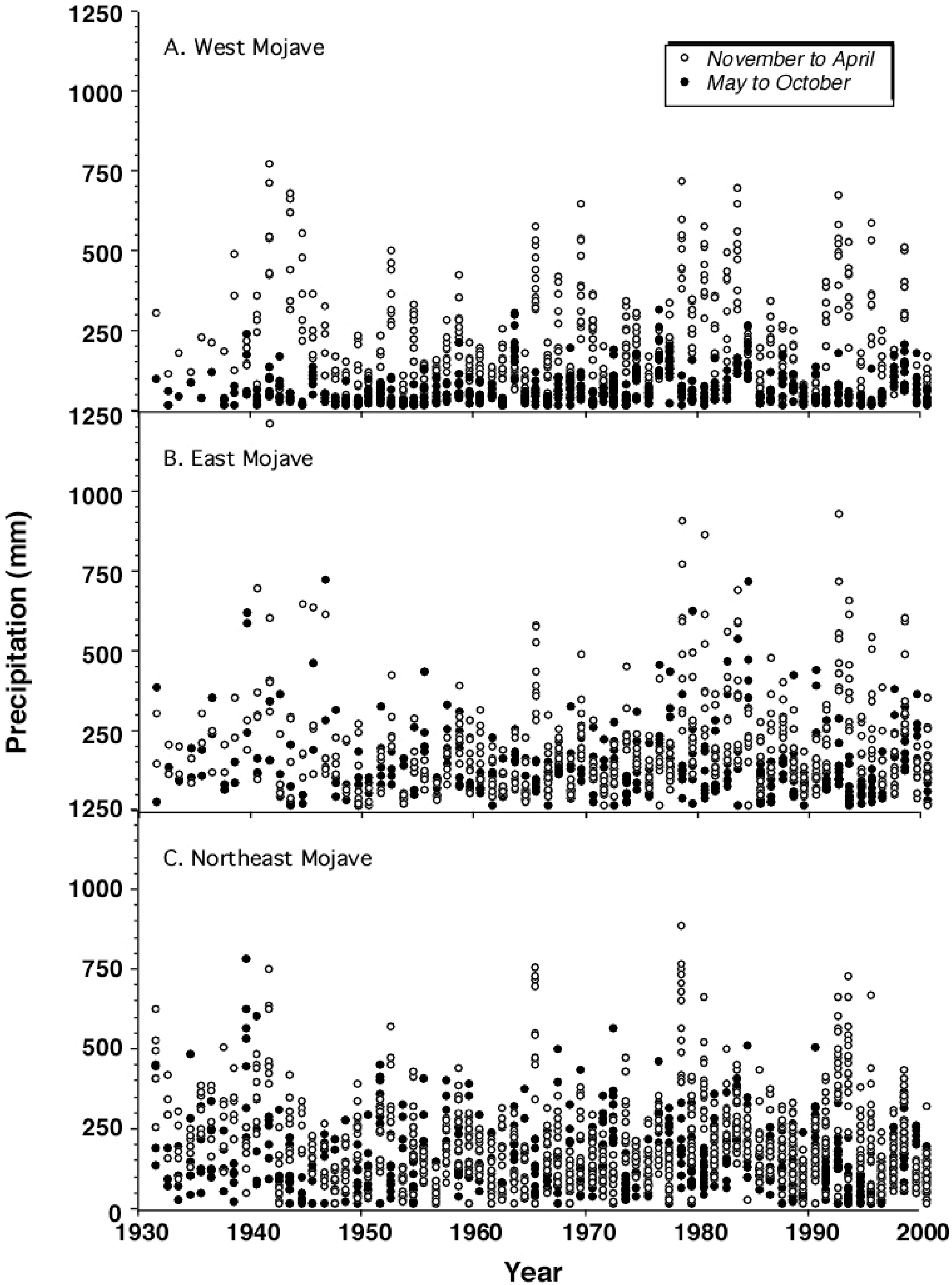


Fig. 4.33 Seasonal rainfall in the Mojave Desert, 1930-2000.

4.3.2 Disease Case Study

Because disease has been such a prevalent issue throughout the range of the desert tortoise, it seems appropriate to consider it in some depth, here, as an aspect of the status of the species' environmental setting. The Recovery Plan mentions two diseases specifically, shell dyskeratosis (section I.B.3) and upper respiratory tract disease (sections I.B.3 and II.D.3.b.1, appendix D.IV.C). Other potentially important diseases not mentioned specifically include herpesvirus (THV) (Pettan-Brewer et al. 1996), iridovirus (Westhouse et al. 1996), and fungus (Homer et al. 1998, Rose et al. 2001) infections. Diseases in general are mentioned or implied for topics such as sources of mortality (section II.D.b.2) and translocation (appendix B.6).

Shell dyskeratosis is not uncommon in both the desert tortoise and the gopher tortoise. The disease may be related to nutrient deficiency or to toxins (Jacobson et al. 1994, Homer et al. 1998, Christopher et al. 2003; E.R. Jacobson, pers. comm.). A direct connection between shell dyskeratosis and population decline in tortoises has not been established. A correlation between the presence of shell dyskeratosis and a die-off of individuals has been reported for a site in California (Berry 1997), yet numerous other threats (Boarmann 2002, and threats section of this report) are also present at that site. In addition, no correlation exists between frequency of shell dyskeratosis and population declines in the Sonoran Desert (citation).

Little was known about the relationship of *Mycoplasma* to tortoise disease when the Recovery Plan was developed. Likewise, the potential relevance to the desert tortoise of studies of *Mycoplasma* in the gopher tortoise was little appreciated when the Recovery Plan was developed. Upper respiratory tract disease (URTD) now is confirmed to be the result of infection by *Mycoplasma agassizii* in both the desert tortoise and gopher tortoise (Brown et al. 1994, 1996). Furthermore, another, closely related, species of *Mycoplasma*, *M. cheloniae*, has been isolated from tortoises, and two more species of mycoplasma are known from tortoises, but not as yet isolated (Brown et al. 2002; M.B. Brown, pers. comm.). Important studies of respiratory mycoplasmal infection in tortoises published since 1994 include Jacobson et al. (1995), Berry (1997), Epperson (1997), Lederle et al. (1997), McLaughlin (1997), Schumacher et al. (1997, 1999), Smith et al. (1998), Brown et al. (1999), and Diemer-Berish et al. (2000). A direct cause/effect relationship between respiratory mycoplasmal infection and population decline in tortoises has not been established, although a provocative correlation between the presence of URTD and die-offs of individuals of both the desert tortoise and the gopher tortoise has been documented at some locations (Jacobsen et al. 1995, Berry 1997, Rabatsky and Blihovde 2002, Seigel et al. 2003; K.H. Berry, pers. comm.; J.E. Diemer-Berish, pers. comm.).

Mycoplasma agassizii is easily transmitted horizontally by direct contact between host individuals (McLaughlin 1997, Brown et al. 2002). Although other mycoplasmas are known to be transmitted vertically from host mother to offspring and via fomite, such modes of transmission have not been demonstrated for *M. agassizii* (Brown et al. 2002). Because *M. agassizii* is so easily transmitted horizontally, isolating infected individuals is an appropriate means to control spread. Isolation of infected individuals is only a part of the general strategy for control of an infectious disease, which should include diagnosis, quarantine, culling or segregation, physical separation, sentinels, and long-term monitoring (M.B. Brown, pers. comm.). How much time, effort, and funds are put into implementing this strategy for a particular disease depends, in large part, on the perceived risk to the host: the greater the perceived risk, the larger the commitment. For example, although the viruses that can cause another upper respiratory tract infection, the "common cold" in humans, are extremely contagious, virtually no control strategy for the pathogens has been implemented, because the perceived risk is low, despite the fact that individuals sometimes develop secondary infections and occasionally succumb to the – largely indirect – effects of the viruses. Assessing risk is particularly difficult in situations, such as those surrounding both the desert tortoise and the gopher tortoise, in which many of the relevant facts that bear on the assessment simply are uncertain or unknown. We return to assessing risk later.

4.3.2.1 What is known and what is not known?

A great deal has been learned about the relationship of *Mycoplasma* to tortoise disease, mostly since the Recovery Plan was developed. It is certain (Brown et al. 2002) that:

- *Mycoplasma agassizii* (strains PS6 and 723) is a cause of URTD
- The pathology of mycoplasmosis involves hyperplastic and dysplastic lesions of the upper respiratory tract
- Clinical signs of URTD vary in onset, duration, and severity
- Mycoplasmosis has a chronic phase and may be clinically silent (subclinical) in adult tortoises
- Infection with *M. agassizii* elicits specific antibody responses that can be detected by ELISA
- The current ELISA may not be able to detect exposure of all tortoises to mycoplasmas other than *M. agassizii*, although some cross-reactions do occur
- The antibody responses to *M. agassizii* are detectable by ELISA beginning eight weeks after experimental infection
- Under experimental conditions, gopher tortoises become ill quicker after repeated exposure to *M. agassizii*
- Colonization of the upper respiratory tract with *M. agassizii* may be detected by culture and PCR, but assay sensitivity is not as high as the ELISA
- Mycoplasmosis is a horizontally transmissible disease

Note, first, that the important information that we know with certainty relates entirely to individual tortoises, and not to populations. We return to current understanding at the level of the population later. Note, secondly, that important uncertainties and unknowns remain even at the level of individual tortoises. For example, it is probable, but not clearly established (Brown et al. 2002) that:

- Pathogenic and nonpathogenic tortoise mycoplasmas exist
- There is variation among strains of *Mycoplasma agassizii* in their ability to cause URTD
- Other species of *Mycoplasma* (such as *M. cheloniae*) also can cause URTD
- Specific antibodies against *M. agassizii* may not confer protective immunity
- *Mycoplasma* may be transmitted by some forms of indirect contact
- *Mycoplasma* may not persist in burrows of infected tortoises

Many of the uncertainties and unknowns **at the level of individual tortoises** warrant increased attention (Brown et al. 2002; M.B. Brown, pers. comm.; E.R. Jacobsen, pers. comm.). In particular, more information is needed about: vertical transmission of tortoise pathogens (on-going studies are examining vertical transmission of both *M. agassizii* and THV), tortoise immunobiology (need information on reagents and functional assays, normal versus abnormal values, and the cellular immune system); tortoise pathophysiology, and hemosiderosis; modes of transmission of tortoise pathogens other than *M. agassizii*; and relative importance of tortoise pathogens (need information on the virulence of species and strains).

Although accruing information about the effects of URTD and other diseases on individuals is an important undertaking, sound management decisions about species recovery require accruing information about the effects of diseases on populations. Unfortunately, virtually nothing still is known about the demographic consequences, either direct or indirect, of URTD. It is suspected that respiratory mycoplasmal infection can affect desert tortoise and gopher tortoise life history traits (survival, fecundity, migration) directly and, therefore, affect population dynamics directly (Brown et al. 2002; M.B. Brown, pers. comm.), but establishing such a connection, if it indeed does exist, requires a more concerted effort than has been made to date. This cause-and-effect relationship has two linkages: Disease → Individual → Population. A suitable research plan, therefore, would need to be designed, first, to establish that disease affects the life history traits of individuals, and, second, to establish that the changes in life history traits of individuals cumulatively affect population dynamics. Although some tortoises with respiratory mycoplasmal infection clearly have died with what appear to be abnormal deaths (Jacobson et al. 1995, Berry 1997, Rabatsky and Blihovde 2002, Seigel et al. 2003; K.H. Berry, pers. comm.; J.E. Diemer-Berish, pers. comm.), other tortoises with the infection have lived what appear to be normal lives for extended periods (e.g., at sites at which seropositive individuals occur, yet at which no substantial declines in population size can be documented; McCoy et al. in review). Unfortunately, the nature of the research to date has been such that cases of the absence of population decline, in the face of respiratory mycoplasmal infection or of subsequent recovery from URTD, have not been well reported. Neither have the fates of random samples of ill – defined broadly – and healthy individuals from the same populations been mapped, as far as we can tell. The connection between the disease and survival of individuals, therefore, remains inferential, and whether or not disease is an important source of mortality (section II.D.3.b.2) remains largely unknown. Declines in the fecundity of tortoises with acute respiratory mycoplasmal infection have occurred, but the best available evidence indicates that they eventually recover (Schumacher et al. 1999; D.C. Rostal, pers. comm.). The connection between the disease and fecundity of individuals, therefore, remains problematic. No studies to date have explored the potential connection between disease and migration of individuals. Tortoises with respiratory mycoplasmal infection may display abnormal physiological responses, such as increased water loss, or behavioral responses, such as reduction in appetite, reluctance to leave burrows, and irregular basking and burrowing, however, which could influence movement patterns (Brown et al. 2002; M.B. Brown, pers. comm.; E.R. Jacobson, pers. comm.).

It seems clear that the dearth of information on the linkage between disease and life history traits of individuals would reduce the linkage between changes in life history traits of individuals brought about by disease and resulting population dynamics largely to speculation. The best published attempt to relate tortoise demography to disease was by Berry (1997). She presented convincing evidence that desert tortoise population densities had declined substantially at two sites (but, see the discussion of permanent study plots and measurement of population densities presented elsewhere). Some individuals at one of the sites were seropositive and/or clinically ill with URTD, and some individuals at the other site exhibited varying degrees of shell dyskeratosis. She concluded (p. 94) that "between 1988 and 1992 the declines of adults [at the site with seropositive and/or clinically ill individuals] are clearly attributable to URTD caused by *M. agassizii*." She is more reserved in her conclusion about the second case (p. 95): "the population decline appears to be linked to the appearance of shell lesions on the tortoises." The evidence that she presents for the cause-and-effect relationship between tortoise population decline and disease in the first case is: (1) prior to 1988, before the appearance of acute URTD, few individuals ever were observed with overt signs of illness or in a dying state, (2) individuals displaying clinical signs of URTD were distributed throughout the site and in adjacent areas, (3) of 27 individuals in a health profile research program, fitted with radio transmitters, 6 died and 11 disappeared between 1989 and 1992. We suggest that this evidence supports a more conservative conclusion, one that is nearer the conclusion that Berry (1997) reached for the other site: the population decline appears to be linked to the appearance of URTD in the tortoises. Note that this conclusion still is immensely important and demonstrates that, at present, disease threats deserve consideration on par with other threats.

4.3.2.2 Risk from disease threats

It appears that URTD is a complex, multi-factorial disease, interacting in some circumstances with other stressors to affect tortoises (Brown et al. 2002; M.B. Brown, pers. comm.). Hypothesized factors contributing to mycoplasmal transmission and URTD disease severity include different critical thresholds of exposure among tortoise populations; difference in virulence among microbial species and strains; prior exposure, which probably limits the ability to control disease severity; variable clinical expression, both temporally and spatially; differences in sex ratios, age structures, and behaviors among tortoise populations; exacerbating factors, such as drought; and tortoise nutritional status (M.B. Brown, pers. comm.).

At present, the accumulating evidence about URTD is a mass of seeming contradictions. No data indicate that URTD is moving through Mojave Desert tortoise populations in a wavelike pattern typical of mycoplasmal spread (E.R. Jacobson, pers. comm.); yet, failure to identify the pattern may have resulted from inadequate serological sample sizes, inadequate spread of sampling effort throughout the range of the desert tortoise, or other, similar, problems (E.R. Jacobson, pers. comm.; see Diemer-Berish et al. 2000, McCoy and Mushinsky in review). Tortoises in the genus *Gopherus* may have maintained a long-term coexistence with the pathogens causing URTD (E.R. Jacobsen, pers. comm.; McCoy and Mushinsky in review); yet, in some places, such as Ft. Irwin, tortoises seem to have been isolated from at least *Mycoplasma agassizii* (E.R. Jacobson pers. comm.; see McCoy and Mushinsky in review), and, in many ways, respiratory mycoplasmal infection in tortoises resembles a new interaction between host and pathogen (D. Thawley, pers. comm.). In general, respiratory mycoplasmal infections have high morbidity but low mortality (Brown et al. 2002); yet, in some places, severe population declines have been hypothesized to be linked to URTD caused by *M. agassizii* (e.g., Berry 1997).

These seeming contradictions reinforce the emerging picture of URTD as a complex, multi-factorial disease. First, as we have seen, demonstrating the two important cause-and-effect relationships Disease → Individual → Population is not easy, and the difficulty is compounded by inadequate sample sizes and inadequate experimental design. Second, the potential effects of URTD, either for individuals or for populations, are inextricably intertwined with potential effects by numerous other threats, and teasing out individual effects, when several factors co-vary, is a difficult analytic problem. Third, changing ecological conditions, whether connected with human activities (e.g., habitat degeneration, McCoy et al. in review) or not (e.g., malnutrition, Jacobson 1994; drought, Berry et al. 2002), may stress individuals, and result in more severe clinical expression of URTD (Brown et al. 2002). Fourth, mycoplasmal infections often are density dependent (e.g., Hochachka and Dhont 2000), and URTD is seen mostly in relatively dense populations (M.B. Brown, pers. comm.), suggesting that some threshold density of tortoises may need to be reached before the infection becomes severe. Fifth, even if the mycoplasmal species responsible for URTD have maintained a long-term relationship with tortoises in the genus *Gopherus*, the pathogens appear to evolve rapidly into novel strains (Brown et al. 2002), suggesting that demographically important pathogenic relationship may occur at the sub-specific level.

The complexity of the disease threat facing the desert tortoise, coupled with the uncertainty surrounding many of the key issues, and the fact that the tortoise is faced with many other threats, suggests that a conservative approach toward disease as a threat be adopted at this time. Although the evidence suggests that disease, especially URTD, could be an important force shaping the demography of desert tortoise populations, the evidence neither demonstrates that disease is a potent force, nor that it is the most important force, nor that it acts independently of others forces. A more balanced, adaptive, and focused approach to dealing with URTD is appropriate at this time, perhaps one modeled on the recommendations of McCoy and Mushinsky (in review) for dealing with the disease in the gopher tortoise. Such a balanced approach would take into account the risks, and associated costs, involved not only of transmitting *Mycoplasma agassizii* among tortoise populations, but also of transmitting the it within populations or to other species. It would deal with the management practice of translocation and of dooming demographically valuable individuals to euthanasia simply because they are suspected of harboring the pathogen. It would deal with underestimating the importance of other pathogens (such as herpesvirus, THV), and of diverting attention and resources away from managing, acquiring, and restoring habitat. For example, if *Mycoplasma agassizii* has a long-term relationship with its tortoise host, then addressing the risks involving habitat loss, fragmentation, and degeneration is crucial for permitting recovery from URTD. Die-offs are likely to have occurred historically, and populations have obviously recovered. Under current conditions, large populations in good habitat likely could recover again, but small populations, or populations in poorly managed habitat, may be in serious danger of extinction. A more adaptive approach would take into account the evolution of knowledge about *M. agassizii* and URTD. Advances in knowledge may necessitate reevaluation of the risks facing the tortoise. For example, if strains of *M. agassizii* are variable in virulence, as evidence now suggests (Brown et al. 2002), then careful isolation of high-virulence strains, on the one hand, and relaxation of the moratorium on translocation of the low-virulence strains, on the other hand, may be warranted and wise. A more focused approach would take into account the ultimate goals of any actions taken against URTD. Different goals may dictate different weightings of the risks facing the gopher tortoise. For example, if the ultimate goal is for populations to be self-sustaining in the face of environmental pressures, including disease, then actions requiring persistent veterinary intervention may counter indicated and dangerous.

The complexity of the disease threat facing the desert tortoise, coupled with the uncertainty surrounding many of the key issues and the fact that the tortoise is faced with many other threats, suggests that the disease threat will not be understood without bringing to bear all of the tools of modern epidemiology, particularly ecological epidemiology. Classical epidemiology primarily is concerned with the statistical relationship between disease agents, both infectious and non-infectious, while ecological epidemiology is concerned with the ecological interactions between populations of hosts and parasites (Swinton 1999). Epidemiologists are aware of the importance of the sociodemographic (classical epidemiology) or the ecological (ecological epidemiology) setting influencing the course that a disease takes in a population, and they are equipped with the statistical tools necessary to deal with diseases resulting from a variety of confounded and interdependent factors and to establish causal chains.

4.3.2.3 Recommendations

An immediate need exists to develop scientifically-based recommendations for management of healthy and ill -- defined broadly – wild tortoises so as to minimize the risk to both individuals and populations of uninfected tortoises (Brown et al. 2002), and, by extension, risks both to individuals and populations of infected tortoises. The focus here is on the two recovery actions recommended in the Recovery Plan most relevant to disease threats in light of this need. These two recommendations still are sound, but suffer from almost complete lack of implementation in the past decade. Here we also list additional recovery actions, which should be seen as simple extensions of the original actions based on new knowledge available today.

4.3.2.3.1 Initiate epidemiological studies of URTD and other diseases (section II.D.3.b.1)

- Refocus the general approach to research on disease, treating it as part of a network of threats to tortoise populations, which, because of negative and positive feedback loops to other threats, cannot be addressed effectively without reference to the threats network

- Develop multi-disciplinary, long-term research agendas to understand the network of threats (a possible model, developed for studying URTD in the gopher tortoise, is attached as an appendix)

- Develop tools to study disease which are not so expensive that they preclude needed resources to research the interactive effects of disease with other threats.

- Develop more knowledge about the ecogeography of genetics of disease and hosts as a way to develop recommendations for translocation programs cognizant of the potential harm that can come from lack of information about mismatches between virulence of genetic strains of pathogens with different strains of host.

- Include epidemiologists and population biologists in developing the research agendas

4.3.2.3.2 Research sources of mortality, and their representation of the total mortality, including human, natural predation, diminishment of required resources, etc. (section II.D.3.b.2 of the recovery plan)

- Add health assessments to the information gathered in ecological studies and monitoring, perhaps using an existing protocol (Berry and Christopher 2001).

- Develop clear standards for determining whether individuals in a population are healthy or not and whether they have been stressed or not.

- Initiate a rapid response program to investigate morbidity and mortality events, using existing programs (e.g., Biodefense, Foodnet) as models (i.e., develop standard operating protocols so that when a die-off event occurs, response actions happen quickly. Develop standard diagnostic and evaluation protocols to determine the nature and severity of a disease threat. Develop appropriate management strategies for containing or removing a disease threat, if necessary. Develop appropriate ways of evaluating the success of the management strategies.

- Continue current serological surveys for *M. agassizzi*, adding screening for THV. Develop surveys for other *Mycoplasma* species as assays become available.
- Continue necropsies (the sample currently includes 74 individuals according to E.R. Jacobson). Develop a rationale for these necropsies in relation to the potential for information from them to affect new knowledge and management.
- Continue developing, improving, and extending diagnostic tests. This includes developing less expensive and more field-portable testing.
- Continue developing stress tests that are applicable to wild tortoises (e.g., adrenocorticotropin hormone (ACTH), phytohemagglutinen (PHA), and sheep red blood cell (SRBC) challenge experiments, to examine adrenal gland response, T-cell response, and B-cell response, respectively; P. Kahn, pers. comm.)
- Inform researchers about both the qualities and the shortcomings of diagnostic tests (see Brown et al. 2002); for example, that clinical signs of URTD may be non-specific or specific host responses to agents other than mycoplasmas, that seropositive (ELISA) individuals may display no overt clinical signs of URTD, and that ELISA alone often is not sufficient, largely because they indicate only past exposure, and not necessarily current infection
- Inform researchers about the value of different diagnostic tests in addressing different goals (see Brown et al. 2002); for example, different tests are appropriate for health assessment of an individual tortoise, for a population survey, for long term population monitoring, and for investigation of a mortality event.
- Ensure that all important information is made accessible to researchers.
- Ensure that the expedient course of killing seropositive, but otherwise healthy, individuals is kept to a minimum.

A caveat to these recommendations is in order. Many modern epidemiologists do not think that epidemiology itself should be concerned with the delivery of services or with implementation of policy (e.g., Savitz et al. 1999). Regardless of whether or not one agrees with this viewpoint – which reflects a similar viewpoint common in conservation biology – it points to a separation between the scientifically-based accumulation of knowledge and the ultimate use of knowledge. The recommendations made here are for improving the science surrounding disease as a threat for the desert tortoise, and may not necessarily provide an easy transition to management strategies. Designing management strategies for a complex disease threat, particularly one in which the factors contributing to the complexity may themselves be threats – which is an unusual situation – is a daunting task; however, the response to this daunting task must not be to ignore the complexity in the name of expediency.

5. Linking Impacts. Habitat, and Demography to Recovery

5.1 Cumulative, Interactive and Synergistic Impacts of Multiple Threats

Desert tortoise recovery is fundamentally a demographic process. Populations increase, decrease, or remain stable largely because of the net effects of several important demographic factors: birth rate (natality), survivorship (recruitment into the breeding population), fecundity, and death rate (mortality). Most recovery actions for threatened and endangered species are designed to stabilize population size (lambda at 1.0 across generations) where population size is sufficient to safeguard against extinction and to increase population size (lamba > 1.0) where population size is small enough to threaten extinction. Population increase can be achieved through actions that increase natality, increase recruitment, increase fecundity, decrease mortality, or some combination of these. Because the action taken depends in part upon the factors responsible for population declines, it is important to know what forces are impacting declining populations. These forces were addressed in Appendix D of The Recovery Plan (USFWS 1994), by listing each identifiable force and presenting evidence that it is indeed a threat to population well being.

Our task was to determine if, in the past 10 years, new information has been generated that would change the original Recovery Team's (USFWS 1994) evaluation of threats to Desert Tortoise populations. For this analysis, we made use of a recent objective analysis of evidence pertaining to threats to desert tortoise populations (Boarman 2002). The recovery plan identified a large number of important threats to tortoise populations. However, the original plan did not appreciate the complexity of interactions of threats and the insidious nature of the synergism that can occur among threats. In particular, the original recovery plan did not appreciate the degree to which one mortality factor can deleteriously compensate for another mortality factor when the first mortality factor has been mitigated through management actions. For example, the original plan did not appreciate that adult tortoises are likely to die from an alternative mortality factor after being protected from a primary mortality factor in an environment of multiple anthropogenic threats.

Some new information exists on the extent of threat posed by some specific activities. For example, feral and unleashed domestic dogs are now thought by many to pose an important threat to tortoises in some parts of the Mojave (Bjurlin and Bissonette 2001), but this issue was barely recognized in 1994. Translocation was portrayed as a likely threat to populations in 1994, but recent research has shown how it may be an important element in recovery programs (Nussear et al. 2000). More details are now available on disease (see multiple studies listed in Boarman 2002), raven predation (Boarman 2003), fires (e.g., Brooks and Esque 2002), invasive weeds (e.g., Brook2 2000, Brooks and Esque 2002), military activities (e.g., Krzysik 1998, Berry et al. 2000), and livestock grazing (e.g., Avery 1997, 1998). A little more has been learned since 1994 about a number of other threats to tortoise populations including illegal collecting (Berry et al.

1996), kit fox predation (Bjurlin and Bissonette 2001), handling (Averill-Murray 1999), release of captives (Field et al. 2000, Johnson et al. 2000), roads (von Seckendorff Hoff and Marlow 2002), and noise (Bowles et al. 1997). Most importantly, however, virtually nothing is known about the demographic impacts of any of the threats on tortoise populations or the relative contributions each threat makes to tortoise mortality.

The most significant modification to the Recovery Plan's perspective is a change to emphasize the importance of multiple and synergistic threats that exist in the Mojave. By multiple threats we mean that many factors are simultaneously acting to suppress tortoise populations. By synergism we mean that the manner in which one threat is expressed is determined, in part, by the manner in which other threats are expressed. This results in a situation in which it can be remarkably difficult to identify management actions that are most likely to lead to recovery. The insidious nature of this complex suite of threats is best expressed by example. Overgrazing, for example, may suppress tortoise populations by reducing the availability of important forage plants. However, tortoises that are "saved" by grazing reductions may be lost anyway due to shooting by public land users or may be crushed by vehicles driving on nearby roads. Hence, even though grazing reduction was appropriate and necessary, it was not sufficient because saved tortoises were now available to be lost through the compensatory threat. This new emphasis is particularly appropriate given an apparent increase in the number and complexity of threats facing tortoises since 1994, especially in the western Mojave Desert.

Focusing on individual threats has resulted in little positive measurable change for desert tortoise populations. Some of the reasons why little positive change has occurred have nothing to do with focusing on individual threats, at least directly. The individual threats approach likely did not contribute to a general recovery of the desert tortoise for several reasons, however. For example, the individual threats approach cannot account for compensatory mortality (i.e., if the most important mortality factor for an area "a" is removed, then mortality factor "b," which previously did not seem important relative to mortality factor "a," then becomes the most important mortality factor. In the hypothetical example given above, when mortality associated with overgrazing was removed, it was replaced by poaching and road kills.). A particularly insidious consequence of using the individual threats approach is a problem we term "elevating the expedient to the important." the problem is that a simple listing of individual threats naturally may induce managers to attend first to those threats they view as most tractable, in light of available resources, and those threats may not necessarily produce the best result. The elimination of grazing in an attempt to enhance desert tortoise population growth appears to illustrate the problem. Thus, we believe the most effective management will be based upon recognizing the importance of addressing the multiplicity of threats impacting specific populations.

The cumulative and synergistic effect of multiple threats is often manifested through indirect impacts: habitat degradation and reduced nutrition from habitat degeneration are two of those indirect impacts. Habitat degradation takes many forms and often the occurrence of one form of degradation is correlated with the occurrence of other forms. Three kinds of habitat degradation are centrally important to conservation and the decline in species abundance: habitat fragmentation, habitat loss, and habitat degeneration.

Fragmentation refers to the parsing of habitat into separate segments. This is a spatial phenomenon, but does not refer to habitat loss per se. For example, a fence or road that forms a barrier to tortoise movement divides a tortoise population into two units without significant habitat loss. Habitat loss, on the other hand, refers to the destruction or conversion of previously suitable habitat into a form that is no longer suitable to tortoises. For example, urbanization leads to habitat loss for desert tortoises. The tortoise population declines due to overall loss of habitat although habitat loss does not necessarily fragment a population. Lastly, habitat can degenerate, meaning the value of the habitat for tortoise survival and reproduction is reduced, even if the habitat is not fragmented or destroyed. Habitat degradation can by particularly insidious problem for wildlife managers because it can be difficult to recognize that seemingly suitable habitat that actually is deficient in some important way.

Nutrition is important to desert tortoise population dynamics due to the role of nutrition in growth, health, and fecundity of tortoises. The availability of nutrition to tortoises in the Mojave ecosystem is naturally variable in response to annual variation in precipitation, temperature, soil moisture, and plant community responses. Some years are forage rich and others forage poor. This is an example of a natural interaction between abiotic factors (weather) and biotic factors (native plant community) influencing tortoise populations through the indirect pathway of nutrition (see Fig. 5.1). However, anthropogenic factors introduce a suite of new factors that ultimately bear on tortoise nutrition through more complex synergistic effects. For example, the replacement of native forbs and grasses by introduced weeds may change the plant community response to precipitation and the nutritional value of the forage produced. Additionally, exotic plants change fire cycles, fugitive dust, the biological availability of water and, perhaps, tortoise movement. The nutritional ecology of tortoises may prove to be difficult to monitor directly, however the threats network may suggest proxy factors that can reasonably be monitored and managed.

5.1.1 Threats Network

We found it easiest to understand the complex synergies between the multitude of anthropogenic activities impacting tortoise populations with a three-tiered conceptual model (Fig. 5.1). The model characterizes biotic, abiotic, and anthropogenic factors in a network of threats to tortoise populations. The premises behind the network are that 1) the interaction of mortality and fecundity determines tortoise density, and 2) density multiplied by available habitat determines total population size. The anthropogenic factors are divided into major land uses (1st tier of diagram), which are composed of one or more specific actions or threats (2nd tier of diagram) that cause tortoise mortality or reduce fecundity via various mechanisms (3rd tier of diagram). The model presented in Fig. 5.1, is most well developed for anthropogenic features of the environment and for factors that negatively impinge on tortoise population viability. This network model represents an hypothesis that needs regular reevaluation and modification by new research and peer review.

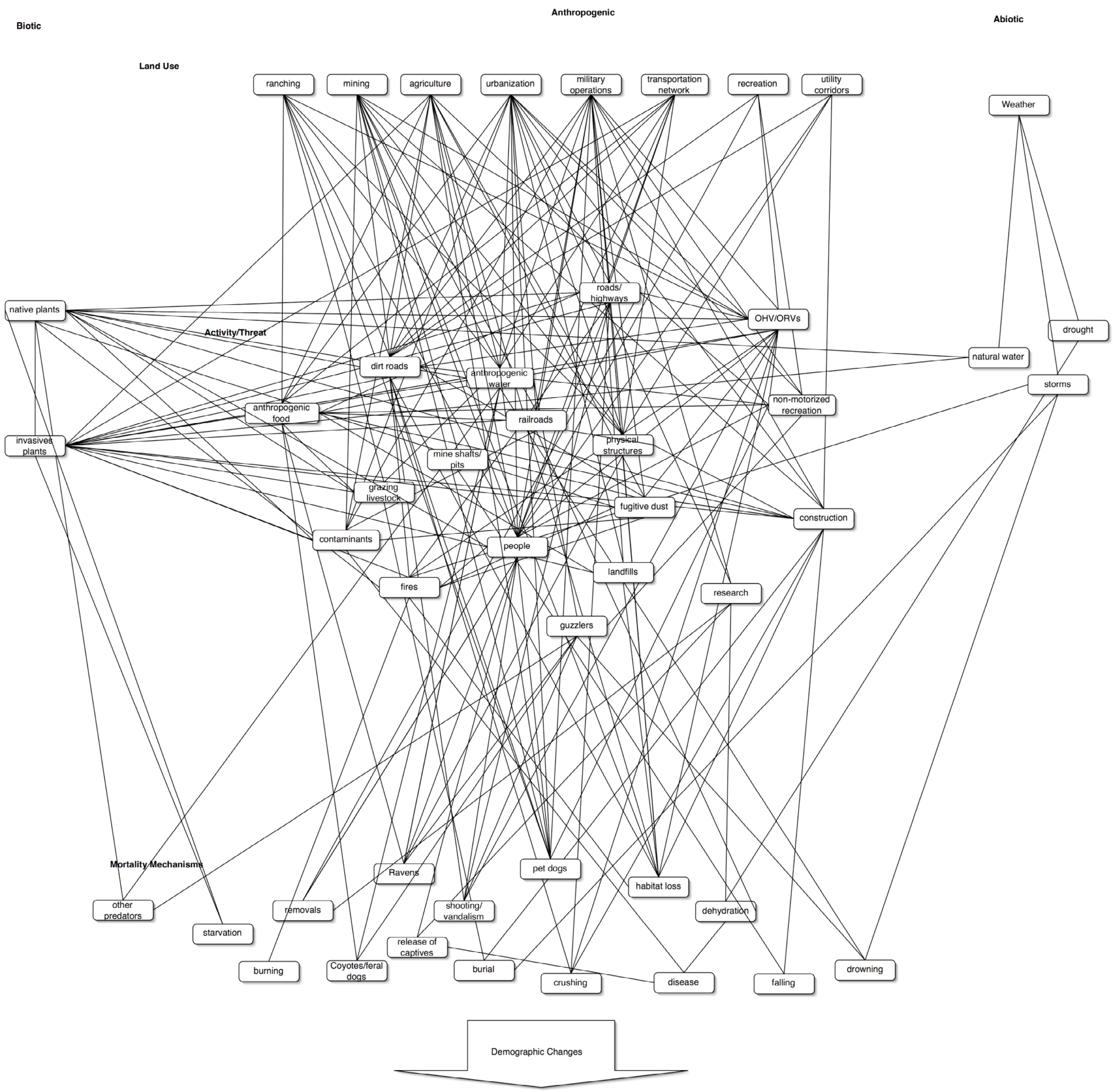

Biotic
Anthropogenic
Abiotic
Land Use
ranching
mining
agriculture
urbanization
military operations
transportation network
recreation
utility corridors
Weather
native plants
roads/ highways
OHV/ORVs
drought
Activity/Threat
natural water
dirt roads
anthropogenic water
storms
anthropogenic food
railroads
non-motorized recreation
invasives plants
physical structures
mine shafts/ pits
grazing livestock
fugitive dust
construction
contaminants
people
landfills
fires
research
guzzlers
Mortality Mechanisms
Ravens
pet dogs
habitat loss
other predators
removals
shooting/ vandalism
dehydration
starvation
release of captives
burning
Coyotes/feral dogs
burial
crushing
disease
falling
drowning
Demographic Changes

Fig. 5.1

The network demonstrates that many human impacts have multiple and different effects on tortoise populations; there are an enormous number of pathways. Hence, focusing on one pathway, even though that pathway is real, may result in inadequate positive impacts on the population. This is because multiple alternative pathways exist to "compensate" by removing animals that were otherwise "saved" by a management action. One way that alternative pathways might subvert management actions is via "compensatory mortality" (discussed above). A second way is via "indispensable mortality." Indispensable mortality refers to the situation in which a species' life table is such that reducing the influence of a mortality factor on certain age classes, typically younger age classes, does not result in a commensurate increase in overall population size. For example, "headstarting" of hatchling sea turtles is not particularly effective in reducing population decline, relative to protection of reproductive females (Frazer 1993), because of the very high mortality rates of intermediate-age individuals. The network also implicitly includes a vortex of feedback loops in which mortality mechanisms from both natural and human impacts differentially affect population size (age) distribution, which affects population recruitment (through fecundity). In other words, not only do impacts from threats cause increased mortality, but a population also loses the ability to rebound from population declines because of reduced fecundity. This inability to rebound is exacerbated when those impacts differentially affect the breeding female and juvenile segments of the population. Various demographic models have demonstrated how impossibly high natality or juvenile survivorship must be to recover dwindling tortoise populations (Congdon et al. 1993, Doak et al. 1994, USFWS 1994).

There are several caveats about the use of the threats network that must be stated at the outset. First, numerous threats may have negative impacts on populations that have time lags that make the effects hard to discern early. Second, affected animals and areas may respond to threats emanating from areas outside of DWMAs. Third, cumulative or indirect effects caused by modification of ecosystems, may also occur. Fourth, threats may have different effects across the landscape. Fifth, the magnitude of various threats may depend upon the initial condition of the landscape and its changes through time. Sixth, the degree of threat by any one factor almost certainly changes in different combinations of interacting threats. Finally, the value of a management strategy depends on the particular problem being addressed. For example, although headstarting (discussed above) might not be very effective in halting decline of an existing population, it may nonetheless become the only option for reintroducing a species to locations from which it has been eliminated.

To illustrate how the threats network can be interpreted, we provide three simplified examples. First, following a very simple thread, we see that four major elements associated with Utility Corridors (Fig. 5.2): construction, physical structures (e.g., power towers, pump houses, etc.), people (e.g., involved in maintenance operations), and unpaved roads. Each one of those elements affect tortoises through various mechanisms; for example, physical structures cause loss of habitat and facilitate mortality from predation by providing nesting habitat for ravens (Boarman and Heinrich 1999). This example shows a relatively straight-forward connection between Utility Corridors and tortoise population declines.

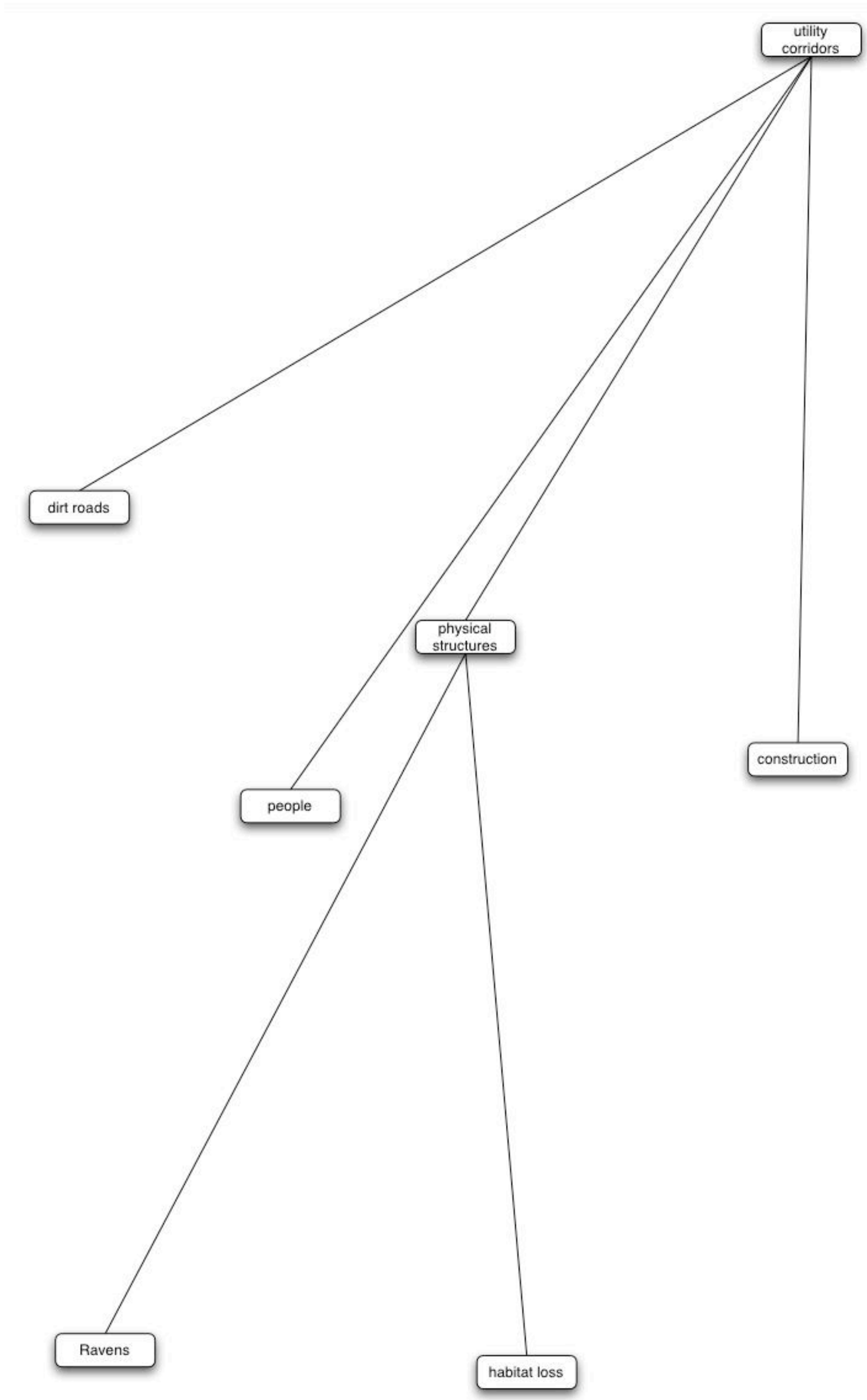

utility corridors
dirt roads
physical structures
construction
people
Ravens
habitat loss

Fig. 5.2

Unpaved roads represent another contributor to threats associated with Utility Corridors further illustrating a much more complex web of connections. On the face of it unpaved roads have relatively few impacts on tortoise populations (e.g., crushing tortoises, habitat loss, air pollution, etc.; Fig. 5.3). However, there are many indirect impacts (Fig. 5.4). For example, unpaved roads, specifically the vehicles on them, cause fires (USFWS 1994, Brooks pers. comm..), which in turn kill tortoises and alter native and non-native vegetation (Brooks and Esque 2002). Roads facilitate the spread of non-native plants (Brooks and Esque 2002, Gelbard and Belnap 2003), which may in turn suppress some native species (Brooks 2000). Unpaved roads also generate fugitive dust (Gillette and Adams 1983), which reduces productivity of plants (Sharifi et al. 1997) and may release contaminants (Forman et al. 2003). Roads facilitate non-motorized and motorized recreation, which can directly, and indirectly, impact tortoise demography (Boarman 2002). Finally, unpaved roads provide access to humans, which can facilitate a large number of activities that may harm tortoises (e.g., vandalism, poaching, release of diseased captives, habitat destruction, dumping of garbage and toxic chemicals, crushing burrows and animals, release of pet dogs that may become feral, etc. Boarman 2002).

An appropriate application to using the model is to identify nodes that have many linkages (incoming and outgoing). Factors represented by these nodes may be key factors that merit focused and priority management action. The next step is to take an hypothesis-driven approach to determine what management actions will have the greatest effects on tortoise populations. We see the new recovery team using this model to make initial recommendations about priorities for management action.

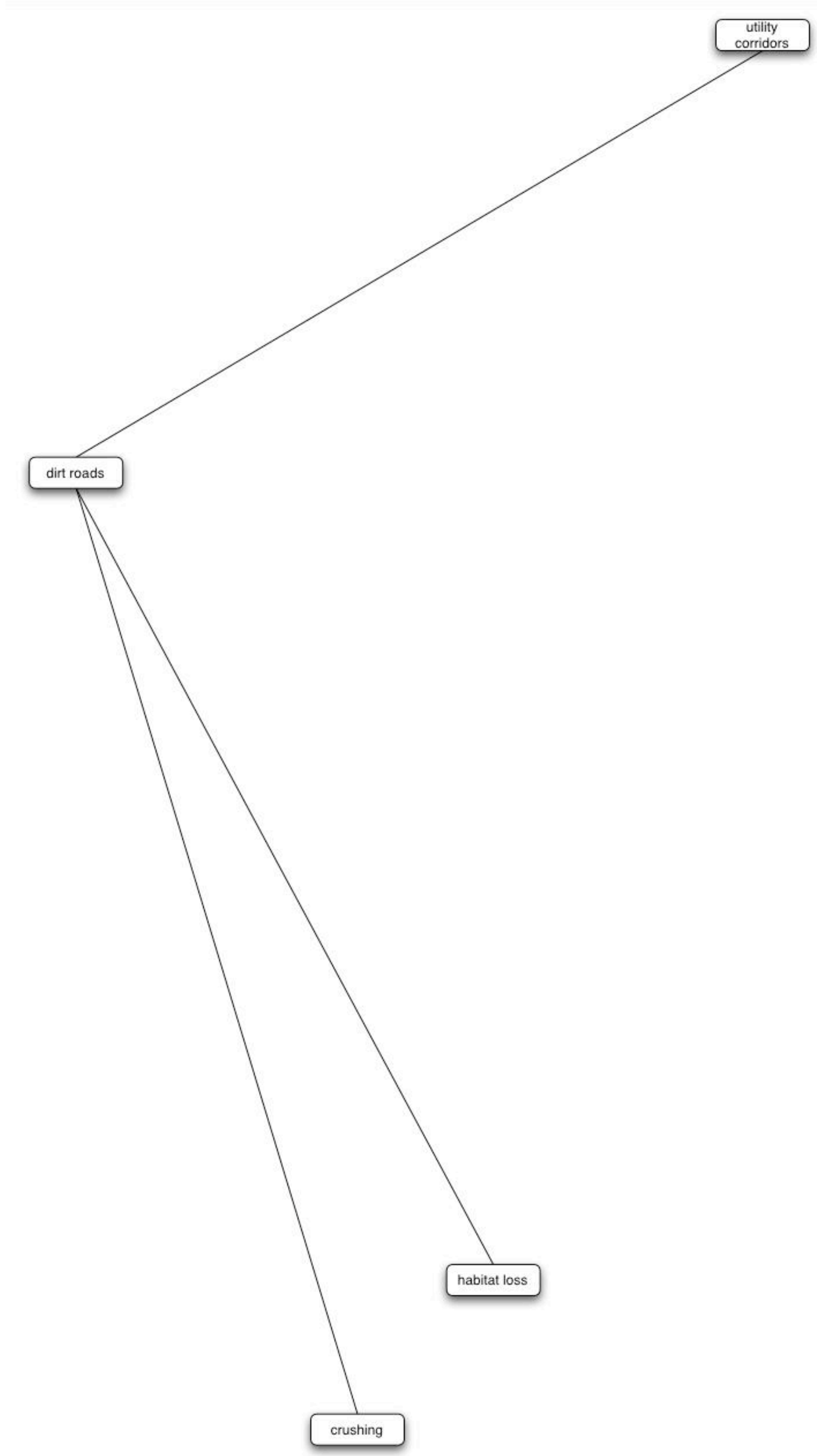
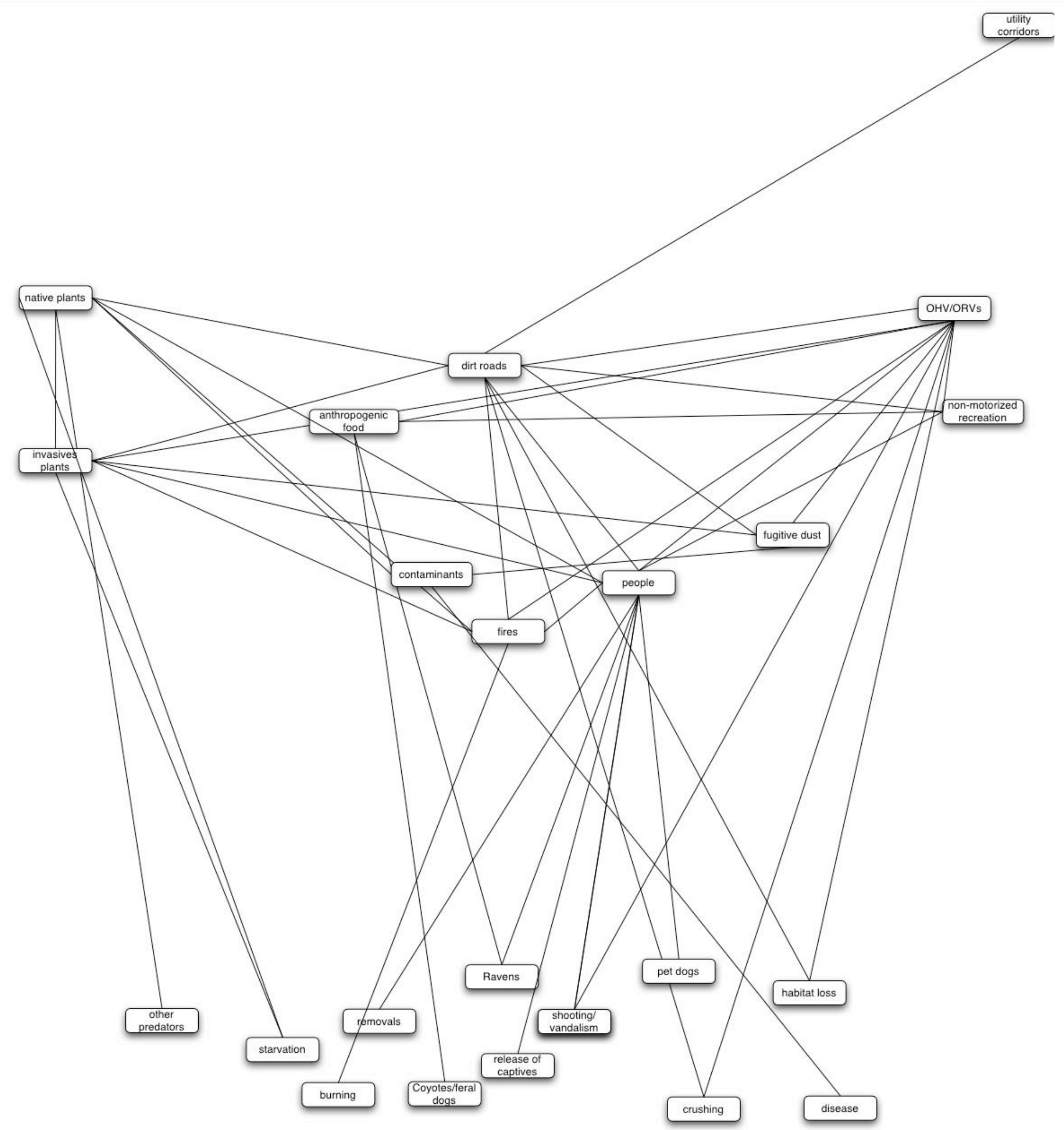


Fig. 5.3



utility corridors
native plants
OHV/ORVs
dirt roads
anthropogenic food
non-motorized recreation
invasives plants
fugitive dust
contaminants
people
fires
Ravens
pet dogs
habitat loss
other predators
removals
shooting/ vandalism
starvation
release of captives
burning
Coyotes/feral dogs
crushing
disease

Fig. 5.4

5.1.2 Multidimensionality to monitoring

Monitoring is employed to assess the "success" of management actions. Success must be assessed by comparing to goals set in advance. Goals and management actions may evolve with additional knowledge, thus, effective monitoring is carried out within an "adaptive management" framework. In the present case, monitoring is employed to assess the recovery status of the desert tortoise. Although population persistence is the ultimate goal of recovery, specific monitoring protocols must accommodate the inherent multidimensionality of the recovery process. Multidimensionality involves the tortoise, habitat, and impacts. Each of these dimensions, in turn, involves multiple scales: individual, population, and species for the tortoise dimension; micro-scale, macro-scale, and landscape scale for the habitat dimension; low, moderate, and high for the impact dimension (Fig. 5.5). The goals of an effective desert tortoise monitoring program minimally should include:

1. Monitoring to assess recovery status of a the desert tortoise
2. Monitoring in a adaptive management framework
3. Monitoring that is multi-dimensional
4. Monitoring that is multi-scaled.

The ability to manage tortoises, habitat, or impacts successfully, and the importance of managing tortoises within an adaptive framework increases as you move across each axis. As you move from the light to dark shades, it becomes increasingly more difficult to manage along particular dimensions and it becomes more important to manage within an adaptive framework (Fig. 5.5). Monitoring should be targeted more towards the darker areas of the graph, as that information tends to be the most important for assessing recovery status (Fig. 5.5). On the other hand, research should target all areas of the box equally. Wherever possible, research should focus on topics that inform management needs and/or directly support monitoring to assess the recovery status of the desert tortoise.

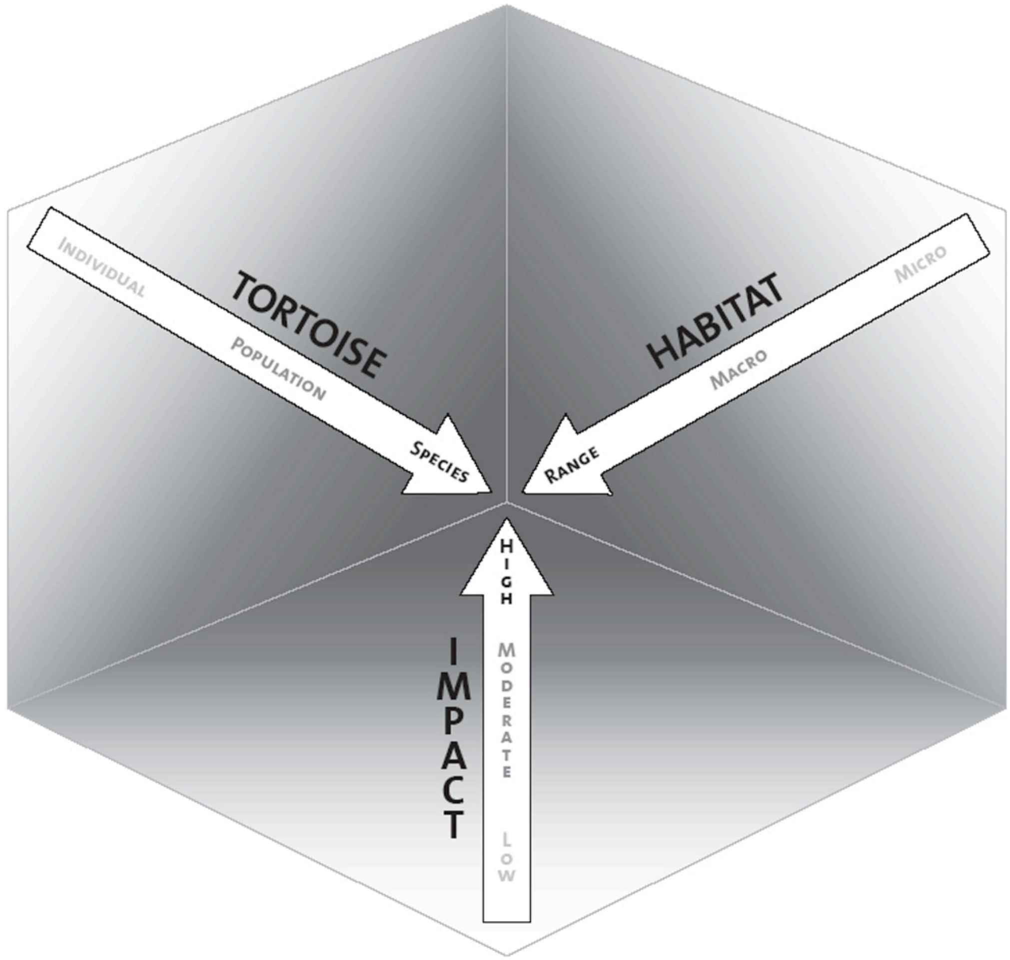


Fig. 5.5 Dimensions of elements important to recovery, and therefore, needing monitoring.

5.1.2.1 Recommendations

The threats network represents a *working hypothesis* of how various factors impact tortoise populations, singly or interactively (as cumulative, synergistic, or interactive effects), whether biotic, abiotic, or anthropogenic. We encourage managers to think about management in terms of suites of threats. Our model firsts posits that many threads threatening desert tortoises include multiple factors or various aspects of individual factors. For example, "livestock grazing" includes horses and burros. Secondly, not all possible impacts, or mechanisms of mortality, are depicted in the model (e.g., minor sources of mortality such as ant predation of eggs are not included). Third, all possible linkages important to describing interacting threats may not be included in this model. The connections we chose to include are only those with a more apparent probability of occurring (i.e., with strong empirical or theoretical support) and that likely do not occur only rarely (e.g., meteor falling on a burrow or a tortoise finding, swallowing, and being injured by a balloon.). Finally, each linkage is equi-probable and equally important.

We offer the following recommendations for changes to the recovery plan:

- Research and management should, through a hypothesis-based approach, focus first on those actions/threats that contribute to a greater number of mortality mechanisms (i.e., involve more linkages in Fig. 5.5) or that affect size structure or fecundity.

- The relative strengths of hypothesized connections between threats and mortality should also be assessed (some individual linkages may be more important than multiple linkages from other individual threats). This assessment should be based on data from research designed specifically to elucidate relationships between threats and mortality.

- Data from the previous two recommendations should be combined into a classification system that characterizes threat by spatial extent, frequency, predictability, and intensity.

- Develop and use innovative methods, including GIS and other types of visualization technologies, to visualize and display the temporal and spatial complexities of individual and interactive threats.

6. Monitoring and Delisting

6.1 Strategies of Desert Tortoise Monitoring

6.1.1 Scope and purpose of monitoring

The purposes for monitoring are manifold. For example, monitoring data and analyses are necessary to assess the efficacy of management actions, monitoring can alert managers to catastrophic changes in population size, habitat loss, proliferation of threats, etc. Monitoring data and analyses will be the basis for delisting. However, the current monitoring program is one dimensional, in that, monitoring is only done for densities of tortoises, and thus will never inform management to its full potential. We recomment that monitoring should be a multidimensional program, including monitoring of populations, but also monitoring the extent and condition of habitat, and monitoring threats to tortoises as well. The goals of an effective monitoring program minimally should include:

- Monitoring to assess the status of populations, habitat, and threats to tortoises
- Monitoring should assess the recovery status of a DPS to indicate whether populations within a DPS should be delisted, or adjustments should be made to current management, or even changes to listing status in view of changes to recovery. Thus, monitoring should drive adaptive management of effective programs for recovery.

All monitoring should be hypothesis driven. There should be clearly defined questions and purposes. Monitoring should never be conducted "to do monitoring" just for the sake of monitoring. Additionally, monitoring should be multi-scaled, or in other words comprehensive (e.g. monitoring should include individuals as well as populations, micro-habitat as well as macro-habitat, etc.). The types of questions that could be asked of a multi-dimensional, multi-scaled, recovery focused, and adaptive management integrated monitoring program include:

a. Are there enough tortoises in the DPS for the population to be self-sustaining?

b. Is the criterion of a 50% of persistence for 500 years the best criterion to define recovery?

c. Is the condition of the habitat within a recovery unit improving or getting worse?

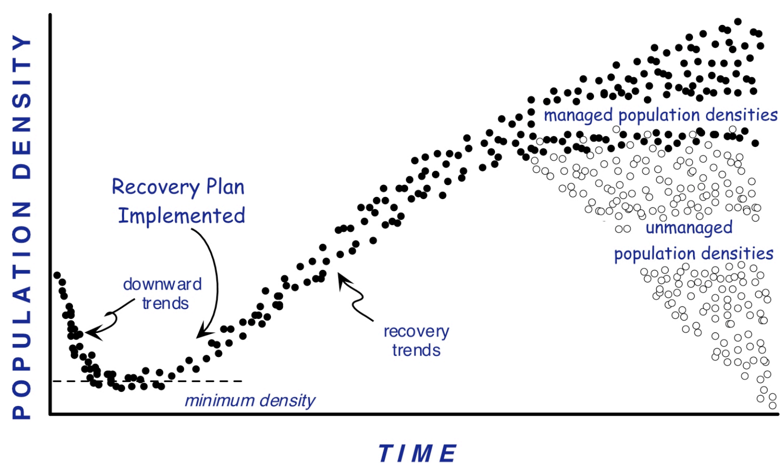
d. Is the effective area contained within the DPS being reduced?

e. Are threats to tortoises increasing or decreasing in the DPS?

6.1.2 Multi-dimensional Monitoring Strategy: Populations, Habitat and Threats

The keystone-delisting criterion in the recovery plan for Mojave Desert Tortoises is: "As determined by a scientifically credible monitoring plan, the population within a recovery unit must exhibit a statistically significant upward trend or remain stationary for at least 25 years (one desert tortoise generation)" (Fig. 6.1). This criterion was promoted by the original desert tortoise recovery team instead of a more common criterion specifying a target population size required for delisting (At the time when the desert tortoise was listed by USFWS, there was a downward trend in population size). The other four delisting criteria for desert tortoise relate to conservation actions required after an upward trend has been achieved.

Fig. 6.1 Idealized population trends before recovery planning implemented, as a result of implementing recovery planning, and after delisting.



Historically, monitoring has centered on the tortoises themselves and not on monitoring their environments or threats. The example, the Desert Tortoise Recovery Plan, Appendix A, (Fish and Wildlife Service 1994a) outlined the need to determine regional densities of desert tortoises to determine if population sizes remain stable, increasing, or declining. Originally, desert tortoise populations were monitored using the strip transects (Berry, 1979) or plots (Berry, 1984a). Both of these approaches have provided data on local desert tortoise densities with varying degrees of accuracy, yet neither of these approaches were designed to provide regional density estimates.

Modern monitoring requires going beyond simple tracking of population densities, and expanding to document changes in three elements of importance to recovery:

1. size of populations,
   a. population size includes measures of population density, and
   b. aerial extent of population,
2. habitat of the species, and
3. threats to populations.

In addition, monitoring should be hypothesis-based. For example, hypothesis-based monitoring could be used to determine the effects of management actions such as highway fencing or removing grazing. Presence/absence data can be used to identify areas that could be targeted for repatriation experiments or other research projects needed for assessing the efficacy of management. For example, data on presence and absence of tortoises collected as part of a project to estimate population density of desert tortoises were used in a Kernel Analysis of the statistical presence of desert tortoise. This analysis revealed areas in which tortoises were found formerly and now are statistically absent. A similar Kernel Analysis of carcasses showed that the same geographic area had a higher concentration of carcasses. Thus, it would be fair to say that the Kernel Analyses of presence and absence show an example of where there was a failure of management to maintain tortoise numbers in a parts of a designated Desert Wildlife Management Areas (DWMA) and USFWS Critical Habitat. Specifically, in an area that was formerly in the range of desert tortoises, there appears to be no remaining population (Fig. 6.2). A GIS analysis of this extirpation illustrates that the consequence of this loss is greater than just the loss of the individual tortoises. For example, the Desert Tortoise Natural Area (DTNA) has become a fragment of habitat separated from the rest of the DWMA to which it belongs. The same damaging results have occurred in Eldorado Valley, Nevada.

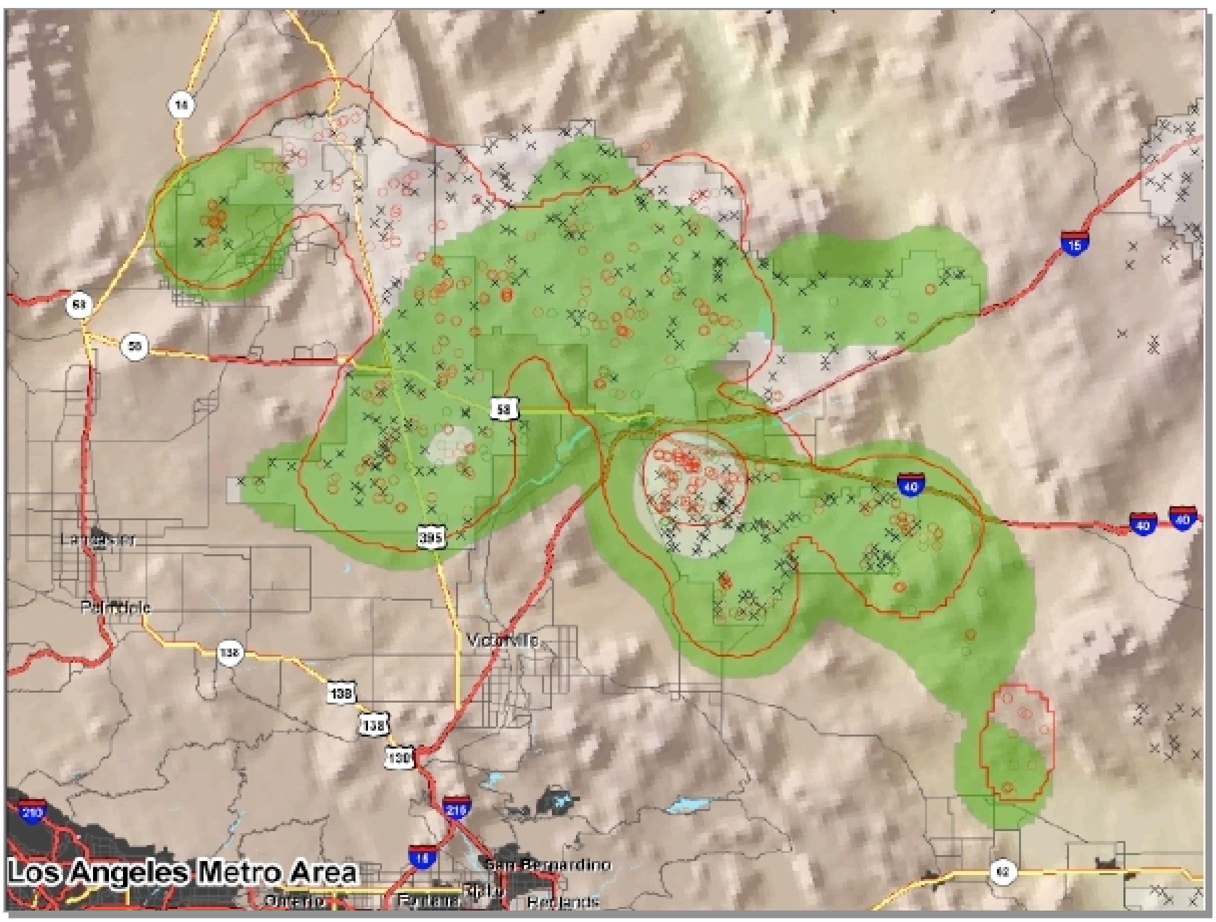


Fig. 6.2 Kernel analysis of presence data for living desert tortoises (green polygons) and carcasses (red outlines.

6.1.3 Monitoring Population Trends

Insofar as assessing trends in population numbers is necessary to assess the efficacy of management actions and/or to determine when delisting is warranted, then it is necessary to be able to discern a population trend. Additionally, that trend must be discernable regardless of the variation in periodic estimates of population size (whether that variation is caused by actual variation in population numbers or errors in estimates of population size). With little variation in data, statistically determining a population trend is a simple task (see Fig. 6.3). However, large variance in population density estimates for desert tortoises can make determining a trend very difficult (or impossible). The life history characters of desert tortoises make discerning population trends difficult over a short time (e.g. 25 years;see Fig. 6.3). This type of problem has been previously demonstrated for bald eagle populations (Hatfield 19XX).

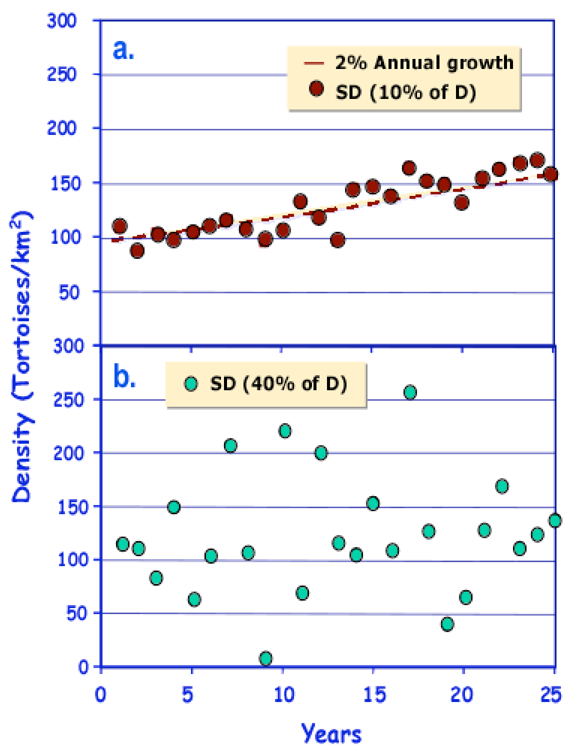


Fig.6.3 Simulated population growth at a 2 % growth rate with (a) a 10% coefficient of variation around the trend, and (b) a 40% coefficient of variation around the same trend.

6.1.3.1 Long-Term Study Plots

- Long-term study plots were established in the early 1970's as part of an inventory of Bureau of Land Management **resources. See section 4.1.1.1 for description of plots and methods used.**

6.1.3.2 Transect Methods for Density Estimates

Data Reduction - Calculation of animal density generally requires mathematical adjustments to account for the extent to which a population can be sampled. Thus, one has to know the probability that tortoises are active and able to be sampled(termed g_0 in distance sampling). Additionally, one has to measure detectability, (termed P_a in distance sampling) which is the probability that animals can be seen by the person walking a transect.

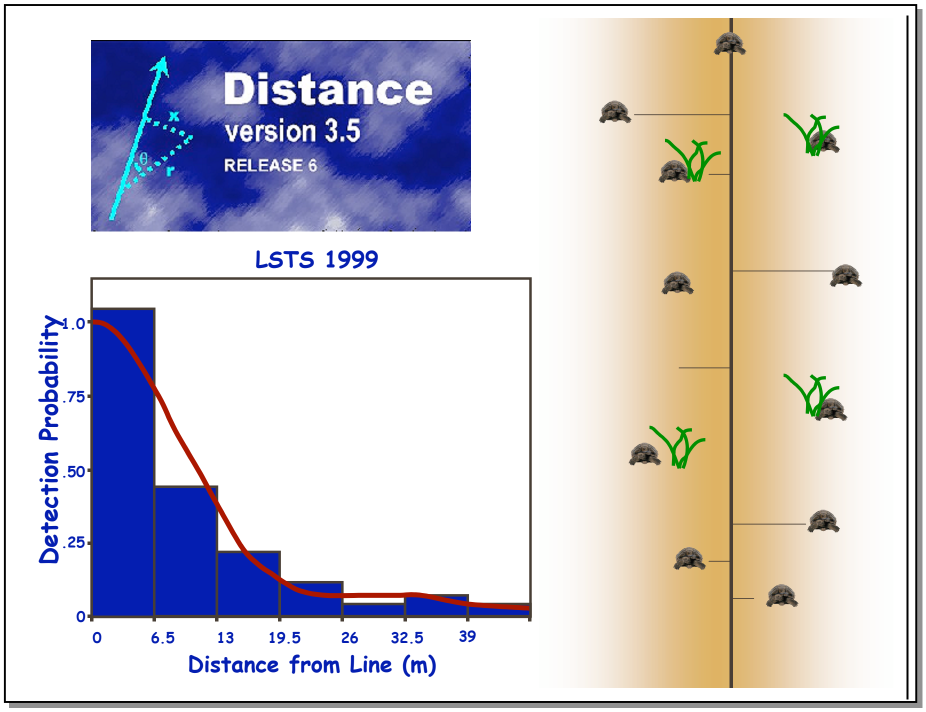


Fig. 6.4 An illustration of the distance sampling technique. Fewer tortoises are seen at distances far from the line. A detectability curve (P_a) is created by modeling the successive distances of tortoises from the transect line.

In distance sampling, animals located further from the transect line are more difficult to see. The perpendicular distances from the transects to the animals can be used to calculate P_a (Fig. 6.4). The frequency distributions of distances from the transect are normalized assuming that all tortoises on the transect line are seen. The area under the curve of the frequency distribution is P_a (Fig. 6.4). The rule of thumb used is that about 60 tortoises are required to obtain a well-formed frequency distribution, which is requiredestimate detectability. In better years, a person must walk more than 400 km to see 60 tortoises, and in some years, it is necessary to walk more than 1000 km to find 60 tortoises (Medica pers. comm.). Because it takes so many kilometers to obtain an adequate sample, more than one field crew must contribute data to form a transect long enough to calculate Pa. When this occurs, the Pa calculated using Program Distance is **always irretrievably incorrect** because it unduly emphasizes the contribution of the teams that are better able to detect tortoises and this will **always result in population estimates that are too low by an unknown factor**.

The availability of tortoises to be sampled (g_0) changes among sites, at different times of the day, at different seasons, and among years (Fig. 6.5). However, data from the entire range are currently lumped to calculate a single g_0 to correct density estimates of tortoises for the entire range. Tortoise activity is calculated using a small number of focal tortoises, which are monitored to find the proportion of animals that are active. Another possible source of error is that tortoises that can be seen in their burrow are enumerated using the tacit assumption that those tortoises have the same availability and detectability as tortoises found walking in the open.

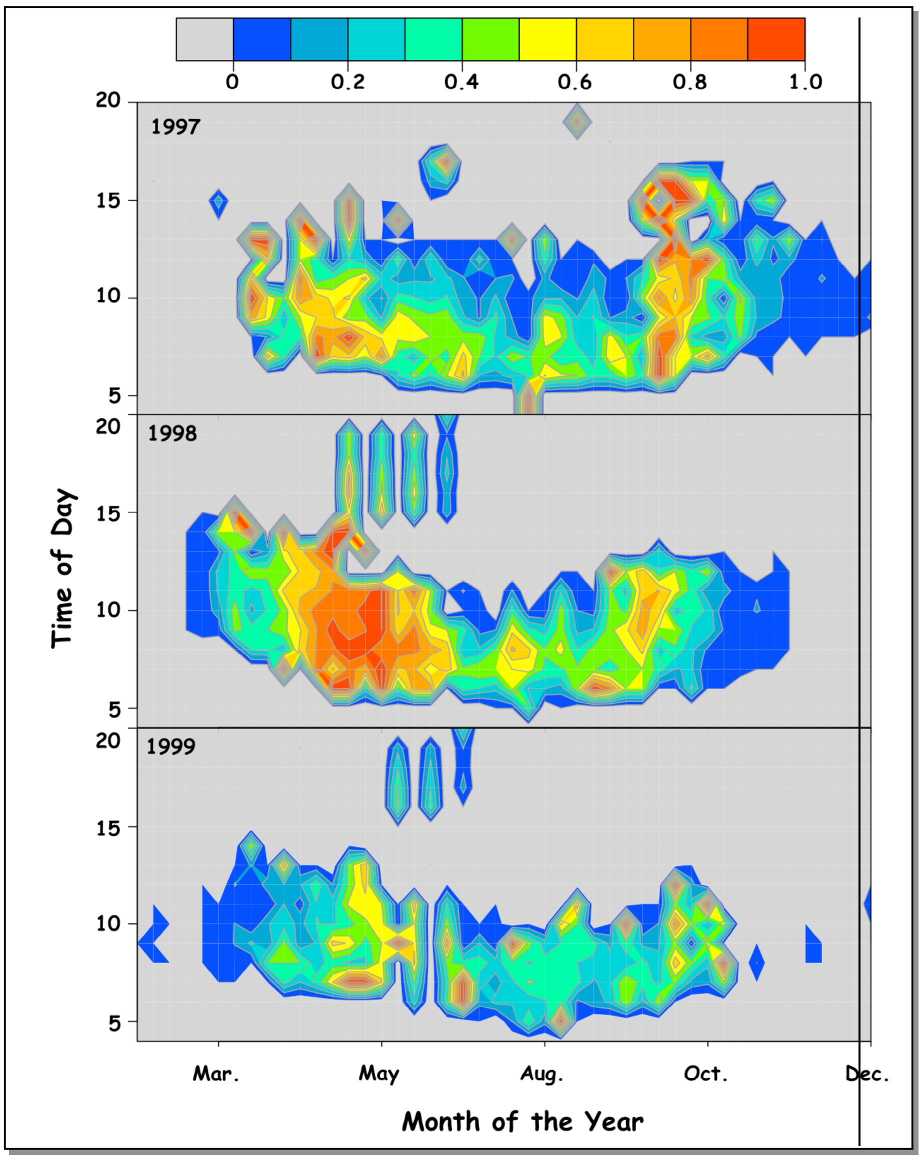


Fig. 6.5 Tortoise activity measured over a three year period at Bird Spring Valley, NV. Tortoise activity is expressed as the proportion of animals active for each hour during each week of the year, and ranges from 0 to 1. The gray areas represent times for which tortoise activity was not sampled. Warmer colors indicate high proportions of animals active, and cooler colors indicate fewer animals active.

Although tortoise densities should be easy to calculate using distance sampling (because tortoises are diurnal, tortoises are found in open habitat, and their activity is linked to drought severity index), it is not always the case that tortoises are easy to enumerate. Tortoise positions that are cited while sampling are burrow (visible), deep (not visible), open, under vegetation, hidden, tortoise in the open but near burrow. For each recovery unit the percent activity of focal animals (5-18) is measured. The mean of observations during when observations are being taken is calculated. Unfortunately, the software used to calculate tortoise densities (Program Distance) currently only allows the use of only one value of,g_0 and this is a serious limitation to the analyses. New software needs to be developed allowing those working with desert tortoises to account for all the variables affecting tortoise activity and detectability.

Power Analysis - A power analysis was performed to estimate the ability to detect trends in population size in relation to different reasonable annual percent population growth rates, with ranges in error encompassing those encountered using distance sampling. For an entirely reasonable gentle growth rate, the coefficient of variation would have to be much lower than current technologies allow in order to detect a trend statistically. Currently, those working on distance sampling are trying to reduce variance in P_a and g_0, but it may be impossible to reduce variance enough to be able to detect subtle trends typical of the natural growth rates of tortoiss populations. Therefore, transect methods minimally require modifications to increase the precision of population estimates to the point where they may be useful for analyses needed for delisting. The detection of steeper trends, such as those of tortoise populations in the West Mojave is currently possible with the level of variation achieved using distance sampling.

Various scientists are working on modifications to the way data are collected, and exploring and evaluating new approaches to analyzing data. These modifications include the length and shape of the transects, the number of technicians working on the transects, the manner in which the data are collected, the configuration of random start locations for the transects, the areas included/excluded for sampling, etc. Each of these approaches needs to be evaluated in terms of the potential to discern subtle trends in population growth. Attempts have been suggested related to the tradeoffs between the precision of data points and the number of data points, which can be governed by doing analyses on averages across years. However, the loss of statistical power by reducing the degrees of freedom for the analyses invariably dominates our ability to discern trends statistically.

One proposed change to population enumeration using transects is to have a team walk until a tortoise is found, and then estimate density for each transect using the value of P_a obtained from sampling known densities of styrotorts during the training classes. This would be a logistical problem because sometimes great distances are required to find a single tortoise. An alternative to this proposal is to use Pa from the training classes as a covariate in analysis. Fuse data within teams and then adjust for team variation with each team P_a.

Clearly, population enumeration via distance sampling needs constant revision and evaluation including evaluating the efficacy of the approach all together.

Recommendation for improving monitoring of desert tortoise population densities

1. All monitoring should be hypothesis driven. In other words, all monitoring should be framed as experiments designed to test pre- and post-management actions

2. Data on the status of habitat and threats should be collected in and of themselves but also as part of tortoise density monitoring so as to extend the scope of density analyses.

3. There should be a top-down organization of personnel to conduct monitoring in such a way that a formalized process if followed for data collection, quality control, and data archival. Standardized data collection and data sharing will allow collaboration so that meta-analyses, and analyses beyond the calculations of tortoise densities can be done. All parties who collect monitoring data should have an agreement for data sharing/pooling as well as agreements on publication of the data/analyses.

4. There should be a science team formed to advise the FWS on how to make, and keep, the monitoring efforts scientifically credible, and to help adaptively manage monitoring efforts to be as efficacious as possible. This team should also help in the prioritization of monitoring efforts.

5. There should be external peer review by an independent panel of experts that would periodically review the monitoring program and the science advice given.

6. There is value in permanent study plots only if the data are used more fully. This value is based on the availability of raw plot data. Without the ability to pool data from all areas and projects, plot data are not nearly as useful. It is difficult to justify amount of money spent on data collection from plots without having open access to the full data set.

7. Inter-agency coordination should be imposed to acquire all necessary data for analyses.

8. There should be continued work to modify distance sampling to get the most precise estimates possible. This includes, for example, improving detection rates and adding environmental covariates in models of population density.

9. There should be an attempt to determine the maximum rate of growth or decline detectable by the most optimistic methods. This would produce an answer to the question, “in the best of all worlds, is there power to detect a certain level of decline, or increase?”

10. If distance sampling is shown not to have enough power to track population trends, then it may be necessary to redirect effort towards detecting trends in other objects or processes such as changes in carcass density or tracking die-offs, etc. The downside to this suggestion is that some objects or processes may have a time

lag that would preclude seeing a decline in adequate time to respond with a change in management.

11. The method of MacKensie et al. (2002) looking at presence/absence should be explored as a means to enhance monitoring.

12. Monitoring should be pitched to detect change at different scales or levels of integration (Bartholomew 19XX).

13. There may be value in considering use of 5-10 key permanent plots per management area (e.g. DPS, or DWMA) as indices of change. This would involve abandoning sampling otherplots.

6.2 Habitat monitoring

Remote Sensing - Mary Cablk (Desert Research Institute) presented to the DTRPAC a strategy for using remote sensing to monitor changes in habitat and threats. Aerial photography, digital airborne data, and satellite data are all possible remote sensing technologies that could be used to monitor habitat. Remote sensing will not work well unless the habitat monitoring experts work within the decision making process. Types of habitat features that could be measured using remote sensing include vegetation association, slope, elevation, micro-conditions, elevation limits, geomorphology, and urban/agricultural land, etc. Once tortoise experts have determined which features are important to measure, the spatial, spectral, and temporal resolution of those features must be determined. This approach makes it more likely to capture the essence of habitat and how best to measure it. Change detection analysis would be used to determine seasonal or annual differences.

Habitat Modeling - Chuck Peterson has developed new techniques in environmental and habitat mapping/modeling (Peterson pers. comm.). These approaches determine key features and assess those features along an environmental gradient. This has been done well for some species using simple habitat variables like temperature and moisture. The analysis tools include probability monitoring, logistic regression, or a combination of both.

6.2.1 Multi-scale Monitoring of Populations, Habitat and Threats

6.2.1.1 Individual monitoring

The DTRPAC explored the information about population viability contained in the condition and behavior or individuals. The background on information in individuals is discussed below.

Another possible method for modeling and mapping habitat is to examine changes and variation in the body condition of individuals. This could be a possible strategy for desert tortoise monitoring. Additionally, one could study the changes in occurrence, as well as temporal changes in spatial distribution. It could be useful to develop a bodily condition index for individual desert tortoises that included more information about the healt of the individual than do current indices. A condition index might lead biologists to mechanisms contributing to population dynamics. Dr. Peterson showed us how in snakes there are strong correlations between body condition and reproductive fitness.

6.2.1.2 Comprehensive monitoring

Comprehensive monitoring programs allow biologists and managers to understand the dynamics of a species fully. If applied toward desert tortoises, this type of program would include asking different questions on many **different scales**, ranging from the level of individual (e.g. using an index of condition) to the population level. Measuring the condition of individuals need not be separate from monitoring population size. A condition index may provide evidence for mechanisms behind changes in population size. For example, a measure of condition could potentially link the risk of mortality to individual covariates. That risk could help contrast between a stable and declining population. Using a more formalized monitoring structure allows some pressure to be taken off of requiring high precision of density monitoring (i.e. density measurements are not relied upon to answer all questions about a population). Each scale that is monitored should have different objectives and a coordinated effort for addressing each objective For example, following individuals ("sentinels") could be used to determine extent of certain threats, but not to answer exhaustive questions.

6.2.2a Recommendations

- There needs to be a coordinated, integrative, collaborative, range-wide monitoring program. This program must be comprehensive and multi-scale in its approach. The elements of the program should include the aerial extent of population, density of populations within aerial extent, qualitative and quantitative gain/loss of habitat, quantitative trends for threats, and possibly a condition index of individuals as an indicator of the population status.

- The monitoring program should include an outside panel of experts to evaluate and recommend how data should be collected and analyzed. The DTRPAC and outside experts agreed that a monitoring program is not useful unless it has a centralized organization, which can provide USFWS with information needed to make informed decisions. The centralized program should be rigorous and formal wherein agencies, counties, and municipalities contribute to a centralized fund from which integrated monitoring projects can be funded which adhere to priorities and approaches consensuses on monitoring approaches, data standards, etc.

- Transect sampling should be refined to collect considerably more data. Additional data could include habitat measures such as rainfall, vegetation, etc. as well as measures on individual tortoises such as blood samples for assessing stress, health, genetic distinctness, etc.

- Density monitoring needs to be recognized to have several components: training field crews, field collection of data, data quality assessment and quality control, data archival, and data analysis and reporting. Too frequently in the past, monitoring has expended virtually all funds on field collection of data and the other components that should be included in a comprehensive monitoring program have been neglected.

- If estimates of tortoise density are determined to be too variable to be useful in assessing effectiveness of management actions, then perhaps density estimates should be treated as "density indicators". This approach should be used only after it has been determined that assessing density cannot be accomplished precisely enough to be valuable.

- Continue to use transects sampling as these data are extremely valuable. Modify DISTANCE software to incorporate unique needs for tortoises (including modeling Go and Pa). Do research to find ways to reduce variance in estimates of availability and detectability as well as to avoid bias due to the clumped distribution of tortoises in the landscape.
- A health, or physiological status, index needs to be developed from bodily condition measurements of individual tortoises. The condition index of Nagy (Citation) may not be reliable insofar as that index can be biased by amount of water in the bladder, which can amount to nearly 50% of body mass, and it gives relatively little information on levels of stress, immune system function, etc.
- There should be an attempt to assess the extent to which data on presence and absence of tortoises could be useful to the goals for monitoring.
- Habitat and threats monitoring by remote sensing should be researched.
- There should be a workshop to bring experts on various kinds of monitoring together to map a plan for developing monitoring of habitat and threats. Additionally, there should be a summit on statistical approaches to density monitoring. This summit should bring together statisticians and tortoise biologists to map out a plan for improving density monitoring.

6.2.2b Recommendations on population-level monitoring

1. All monitoring should be hypothesis driven. In other words, all monitoring should be experiments to test pre- and post-management actions
2. Data on habitat and threats should be collected as part of tortoise density monitoring so as to extend the scope of density analyses.
3. There should be a top-down organization of personnel to conduct monitoring as a means to have a formalized process for data collection, quality control, and data archival. Standardized data collection and data sharing will allow collaboration so that meta-analyses can be done. All parties who collect monitoring data should have an agreement for data sharing/pooling as well as agreements on publication of the data/analyses.
4. There should be a science team to advise the FWS on how to make, and keep, the monitoring efforts scientifically credible, and to help adaptively manage monitoring efforts to be most efficacious. This team would also help in prioritization of monitoring efforts.
5. There should be external peer review by an independent panel of experts that would periodically review the monitoring program and the science advice given.
6. There is value in permanent study plots only if the data are used more fully. This value is based on the availability of raw plot data. Without the ability to pool data from all areas and projects, plot data are not useful. It is difficult to justify amount

of money spent on data collection from plots without having open access to the full data set.

7. There should be imposed inter-agency coordination to acquire all necessary data for analyses.

8. There should be continued work to modify distance sampling to get most precise estimates possible. This includes, for example, improving detection rates and adding environmental covariates in models of population density.

9. There should be an attempt to determine the maximum rate of growth or decline detectable by the most optimistic methods. This would produce an answer to the question, "in the best of all worlds, is there power to detect a certain level of decline?"

10. The method of MacKensie et al. (2002) looking at presence/absence should be explored as a means to enhance monitoring.

11. Monitoring should be pitched to detect change at different scales or levels of integration (Bartholomew 19XX).

12. There may be value in considering use of 5-10 key permanent plots as indices of change. This would involve abandoning sampling other plots.

13. If distance sampling is shown not to have enough power to track an population trends, then it may be necessary to redirect effort towards detecting trends in other objects or processes such as changes in carcass density or tracking die-offs, etc. The downside to this suggestion is that some objects or processes may have a time lag that would preclude seeing a decline in adequate time to respond with a change in management.

6.3 Delisting Criteria

A power analysis of current monitoring approaches to estimate tortoise population densities shows that it will be nearly impossible statistically to discern population trend of growing populations. However, one of the delisting criteria for desert tortoise requires discerning such a trend. Thus, this criterion needs reconsideration.

Recovery prescriptions included creating areas for intensive management of tortoise populations. Those areas were to be large enough (1000 square miles) to allow the populations within them to decline to as low as minimum population densities (as determined by population viability analyses) and still recover.

Below are thoughts and recommendations for the delisting criteria.

6.3.1 Criterion 1

As determined by a scientifically credible monitoring plan, the population within a recovery unit must exhibit a statistically significant upward trend or remain stationary for at least 25 years (one desert tortoise generation).

6.3.1.1 Possible changes to this criterion

- The criterion of a population remaining "stationary" does not work well insofar as high variance in population estimates make populations trending upward or downward statistically indistinguishable from those remaining "stationary".
- The criterion of remaining stationary exclusively draws attention to population size and not to habitat and threats. Thus, additional criteria concerning the identified ingredients of monitoring need to be included as delisting criteria.
- Delisting criteria should address multiple scales of measurement. Thus, considering only the population level in delisting decisions disregards the information available at the individual level (e.g., relating to physiology and behavior of individuals as indicators of recovery), the population level (e.g., relating to population size and trends as indicators of recovery), and landscape (e.g., relating to ecosystem processes such as habitat fragmentation and/or degeneration as problems in recovery). Any new delisting criteria that include multiple scales of measurement should define the relationships among the monitoring components.
- Delisting criteria that require discerning trends of measures at each level need to discuss power and statistical analyses that deal with both Type I and Type II statistical errors.

6.3.2 Criterion 2

Enough habitat must be protected within a recovery unit, ***or*** *the habitat and the desert tortoise populations must be managed intensively enough, to ensure long-term population viability.*

- There may be more ways to use existing data.

6.3.3 Criterion 3

Provisions must be made for population management in each DWMA so that population lambdas are maintained at or above 1.0 into the future.

- Long-term population management and monitoring are needed as part of this criterion.

6.3.4 Criterion 4

Regulatory mechanisms or land management commitments have been implemented that provide for adequate long-term protection of desert tortoises and their habitat

6.3.5 Criterion 5

The population in the recovery unit is unlikely to need protection under the Endangered Species Act in the foreseeable future. Detailed analyses of the likelihood that a population will remain stable or increase must be carried out before determining whether it is recovered. (a) Fluctuations in abundance, fecundity, and survivorship; (b) movements of desert tortoises within the area and to or from surrounding areas; (c) changes in habitat, including catastrophic events; (d) loss of genetic diversity; and (e) any other threats to the population all might be significant and should be important elements that should be considered in such an analysis.

- Wording in this criterion needs to be revised.

6.3.6 General Recommendations

- All recommendations or goals should have specific criteria for assessing success for each DPS. This means recognizing the uniqueness of natural histories, threats, and management in each DPS and managing to preserve that uniqueness.

7. Planning, Coordination, Research, and Cooperation

7.1 Planning and Coordination

The Recovery Plan (p. 3) identified the most serious problem facing the remaining desert tortoise populations in the Mojave region as

> *"the cumulative load of human and disease-related mortality accompanied by habitat destruction, degradation, and fragmentation."*

As a result, the Recovery Plan recommends a list of recovery actions for each DWMA, and many individual actions have been implemented (GAO 2002). Many of these actions appear to have been selected due largely to their ease of implementation, rather than their effectiveness in improving tortoise status. Furthermore, an uncoordinated approach with a suite of management treatments and hit-or-miss assessment of effectiveness is rarely effective for species recovery. Specific diagnosis is needed to reveal the magnitude of how different factors (or combinations of factors) are affecting a species' decline, and that diagnosis should guide priorities for the treatments (Caughley and Gunn 1996).

The Recovery Plan specifically recommended the establishment of "experimental management zones" within DWMAs, in which certain otherwise prohibited activities would be allowed to occur in an experimental context. These zones would allow scientists and managers to determine the effectiveness different management actions. Unfortunately, experimental management zones have not been created, and a primary criticism of desert tortoise recovery efforts to date have been the lack of necessary analyses assessing the effectiveness of specific recovery actions (GAO 2002).

The importance of data-based decision making is already recognized by the U.S. Fish and Wildlife Service and National Marine Fisheries Service in their habitat conservation planning (HCP) handbook. The handbook identifies the need for syntheses of relevant biological data and specific methods for determining anticipated levels of incidental take when describing the impacts of the project covered by a given HCP (USFWS and NMFS 1996). Additionally, FWS specifically recommends adaptive management to adjust to uncertainty due to gaps in scientific information regarding the biological requirements of the species. It is important to allow for changes in mitigation strategies (or other recovery actions) that may be necessary to reach the long-term goals or biological objectives of conservation or other land management plans. Monitoring is essential in an adaptive management program, and it should be designed to ensure proper data collection and scientific analyses. The results of scientific monitoring analyses represent the basis for adjusting management strategies. A key element of adaptive management is the establishment of testable hypotheses linked to conservation strategies and their biological objectives (USFWS and NMFS 1996). An argument against the use of experiments to evaluate management success is that statistical analysis is compromised because of small sample sizes often associated with threatened and endangered species. Caughley and Gunn (1996) dispel this myth by pointing out that statistics answers the question, "Am I justified in accepting the conclusion that the data suggest, given the dearth of data that I have to work with?"

Kareiva et al. (1999) provided several recommendations to improve the use of science in HCPs. We generalize several of those here as recommendations for a revised desert tortoise recovery plan to include in a framework to guide recovery implementation and conservation planning, whether through individual land management plans, habitat conservation plans, or other management activities undertaken to implement the recovery plan:

- provide quantitative biological goals for the conservation/management plan or recovery action;
- plans should include contingencies applied in the context of hypothesis-based adaptive management;
- data must exist, be accessible, and be explicitly summarized and analyzed for the conservation/ management plan to be scientifically credible;
- include explicit acknowledgments describing what data are not available for accurate assessments of uncertainty and risk in the planning process;
- information/data should be maintained in accessible, centralized location(s), and monitoring data should be made accessible to other scientists and managers.

Finally, Kareiva et al. (1999) remarked on the general absence of theory (population genetics, population ecology, behavioral and physiological ecology, island biogeography, community ecology, and ecosystem ecology) in HCPs as a commentary on the major disconnect between academic conservation biology and conservation practice. The GAO (2002) recognized this disconnect with regard to the desert tortoise recovery program when they noted,

> *"No process has been established for integrating agencies' management decisions regarding the desert tortoise with research results. As a result, Service and land managers cannot be certain that they are focusing their limited resources on the most effective actions."*

The need for hypothesis-driven experiments to assess the efficacy of management actions should not be under-emphasized in a revised recovery plan. Other than by coincidence, the effectiveness of recovery efforts depends on the accuracy with which the reasons for decline have been determined (see threats section), and furthermore, we cannot know for sure without an experimental design that an action and any success were causally related (Caughley and Gunn 1996).

7.1.1 Research

The original Recovery Team made several recommendations for research necessary to fill information gaps important to the management of desert tortoise populations. These items included:

a. Obtain baseline data on desert tortoise densities both inside and outside of DWMAs.

b. Develop a comprehensive model of desert tortoise demography throughout the Mojave region and within each DWMA.

   i. Initiate epidemiological studies of URTD and other diseases.
   ii. Research sources of mortality, and their representation of the total mortality, including human, natural predation, diminishment of required resources, etc.
   iii. Research recruitment and survivorship of younger age classes.
   vi. Research population structure, including the spatial scale of both genetic and demographic processes and the extent to which DWMAs and recovery units conform to natural population subdivisions.

c. Conduct appropriately designed, long-term research on the impacts of grazing, road density, barriers, human-use levels, restoration, augmentation, and translocation on desert tortoise population dynamics.

d. Assess the effectiveness of protective measures (e.g., DWMAs) in reducing anthropogenic causes of adult desert tortoise mortality and increasing recruitment.

e. Collect data on spatial variability of climate and productivity of vegetation throughout the Mojave region and correlate this information with population parameters (e.g., maximum sustainable population size, see Appendix G).

f. Conduct long-term research on the nutritional and physiological ecology of various age-size classes of desert tortoises throughout the Mojave region.

g. Conduct research on reproductive behavior and physiology, focusing on requisites for successful reproduction.

Since the Recovery Plan was published, there has been research on some aspects of tortoise biology, in particular nutritional ecology, reproductive physiology, and the effects of some human activities on tortoise populations. A good bit of this research has yet to reach the peer-reviewed literature, and it does not represent a diverse assembly of science bearing on these important topics. Additionally, very little research has been conducted or published on other important topics recommended in the recovery plan, such as long-term demography, effectiveness of recovery actions, and climatic and vegetative variability. On other topics, such as epidemiology and the effects of those human activities not covered above, essentially no research has been conducted or published. Some additional areas of active research, not identified in the Recovery Plan, include disease and health status, habitat conditions, and fire ecology. These areas of research are important and should be continued, however not at the cost of not implementing recovery team recommendations.

7.1.2 Needs from research organized by topics

7.1.2.1 Improving understanding of genetics and the relationships between genetics and other attributes

- Genetic core units need to be assessed using both nuclear and mitochondrial genes.
- Genetic boundaries and gene flow among units needs to be examined critically.

Once genetic data and analyses are available, ecological, morphological and behavioral attributes should be assigned to each of these genetic units. Correlations among established genetic units and carefully quantified and standardized ecological affinities, health status, life history patterns, and stereotypic behaviors.

The natural history of host-parasite associations for the major disease relationships for desert tortoise should be more deeply elucidated including the genetics of hosts and strains of pathogens.

At least three disparate, long-term study sites should be established within each proposed DPS to verify the reality, consistency, homogeneity, and variability of these defining traits

Develop more knowledge about the ecogeography of genetics of disease and hosts as a way to develop recommendations for translocation programs cognizant of the potential harm that can come from lack of information about mismatches between virulence of genetic strains of pathogens with different strains of host.

7.1.2.2 Re-evaluating the status of DPSs and the positioning of DWMAs

Finally, DWMAs within each DPS should be geographically revised to maximize their conservation potential in consultation with ecologists and local resource administrators.

We recommend that the West Mojave Recovery Unit /DPS listing be elevated from threatened to endangered. All analyses, including that from PSP data, to transect data clustering and kernel analyses point out problems that appear to be unique to that region.

7.1.2.3 Improving the value of permanent study plots

If permanent study plot are to continue to be surveyed then there should be some agreement among the surveying agencies to share the data for the greater good of the tortoise. Permanent Study Plots played a key role in this committee's interpretation of the current status of tortoise populations, but it is possible that some of the conclusions reached as a result of our analyses could be different if additional years of data were available. However, the trend from the West Mojave would be very unlikely to be reversed.

There were several recovery units and proposed distinct population segments that contained too few permanent, study plots to be analyzed either with any power, or at all. If PSP sampling is to continue, it would be better if there were enough study plots to represent the different scales of management areas. As a study plot is in itself only one sample, and not representative of an entire area, it would be more beneficial to have several plots within each area upon which future analyses are to be conducted, for example the DPS, or even DWMAs within DPSs.

There is value in permanent study plots only if the data are used more fully. This value is based on the availability of raw plot data. Without the ability to pool data from all areas and projects, plot data are not useful. It is difficult to justify amount of money spent on data collection from plots without having open access to the full data set.

There may be value in considering use of 5-10 key permanent plots as indices of change. This would involve abandoning sampling other plots.

7.1.2.4 Improving the value of transect/line distance sampling

There should be continued effort to modify distance sampling analyses to get the most precise estimates possible. This includes, for example, improving detection rates and adding environmental covariates in models of population density.

If distance sampling is shown not to have enough power to track an population trends, then it may be necessary to redirect effort towards detecting trends in other objects, processes, or indices such as changes in carcass density or tracking die-offs, etc. The downside to this suggestion is that some objects or processes may have a time lag that would preclude discerning a major change in adequate time to respond with a change in management.

Continue to use transects sampling as these data are extremely valuable. Modify DISTANCE software to incorporate unique needs for tortoises (including modeling Go and Pa). Do research to find ways to reduce variance in estimates of Go and Pa as well as to avoid bias due to the clumped distribution of tortoises in the landscape.

7.1.2.5 Improving the values of other tortoise sampling methods and statistical interpretation

There should be an attempt to determine the maximum rate of growth or decline detectable by the most optimistic methods. This would produce an answer to the question, “in the best of all worlds, is there power to detect a certain level of decline?”

The method of MacKensie et al. (2002) looking at presence/absence should be explored as a means to enhance monitoring.

Should tortoise densities be determined to be too variable to be useful in assessing effectiveness of management actions, then perhaps density estimates should be treated as “density indicators”. This approach should be used only after it has been determined that assessing density cannot be accomplished precisely enough to be valuable.

There should be an attempt to assess the extent to which data on presence and absence of tortoises could be useful to the goals for monitoring.

7.1.2.6 Developing tools

Develop and evaluate innovative methods for the visualization and display of individual and interactive spatial and temporal threats, including GIS and other types of visualization technologies.

Develop tools to study disease which are not so expensive that they preclude needed resources to research the interactive effects of disease with other threats.

Continue developing, improving, and extending diagnostic tests for diseases or maladies. This includes developing less expensive and more field-portable methods.

Continue developing stress tests that are applicable to wild tortoises (e.g., adrenocorticotropin hormone (ACTH), phytohemagglutinen (PHA), and sheep red blood cell (SRBC) challenge experiments, to examine adrenal gland response, T-cell response, and B-cell response, respectively)

Habitat monitoring by remote sensing should be developed. This includes monitoring changes in vegetation, appearance or expansion of unpaved roads,

7.1.2.7 Improving the focus on the recovery goal

The relative importance or hypothesized nature of each linkage between impacts and mortality sources should be weighted (based on data), as much as possible. A threat typology could be used to further characterize threats, including spatial distribution, frequency, return interval, rotation period, predictability, intensity, and severity.

Research and management should, through a hypothesis-based approach, focus first on those actions/threats that are more heavily weighted, which contribute to a greater number of mortality mechanisms, and/or which feedback to affect size structure/fecundity.

Refocus the general approach to research on disease, treating it as part of a network of threats to tortoise populations, which, because of negative and positive feedback loops to other threats, cannot be addressed effectively without reference to the threats network

Develop clear standards for determining whether individuals in a population are healthy or not and whether they have been stressed or not.

Provide quantitative biological goals for the conservation/management plan or recovery action

All monitoring should be hypothesis driven. In other words, all monitoring should be experiments to test pre- and post-management actions

Plans should include contingencies applied in the context of hypothesis-based adaptive management;

The need for hypothesis-driven experiments to assess the efficacy of management actions should not be under-emphasized in a revised recovery plan. Other than by coincidence, the effectiveness of recovery efforts depends on the accuracy with which the reasons for decline have been determined (see threats section), and furthermore, we cannot know for sure without an experimental design that an action and any success were causally related (Caughley and Gunn 1996).

7.1.2.8 Developing research agendas

Develop multi-disciplinary, long-term research agendas to understand the network of threats

Initiate a rapid response program to investigate morbidity and mortality events, using existing programs (e.g., Biodefense, Foodnet) as models (i.e., develop standard operating protocols so that when a die-off event occurs, response actions happen quickly. Develop standard diagnostic and evaluation protocols to determine the nature and severity of a disease threat. Develop appropriate management strategies for containing or removing a disease threat, if necessary. Develop appropriate ways of evaluating the success of the management strategies.

Ensure that killing seropositive, but otherwise healthy, individuals is limited. It is imperative to learn the "value" of seropositive animals instead of assuming that they are always a danger.

There should coordinated effort to conduct monitoring including having a formalized process for data collection, quality control, and data archival. Standardized data collection and data sharing is necessary to allow collaboration so that meta-analyses can be done. All parties who receive permits to collect monitoring data should have an agreement for data sharing/pooling as well as agreements on publication of the data/analyses.

There needs to be a centralized, integrative, collaborative, rangewide monitoring program. This program must be comprehensive and multi-scale in its approach. The elements of the program should include the aerial extent of population, density of populations within aerial extent, qualitative and quantitative gain/loss habitat, quantitative trends for threats, and a condition index of individuals as an indicator of the population status.

Density monitoring needs to be recognized as having several components: training field crews, field collection of data, data quality assessment and quality control, data archival, and data analysis and reporting. Too frequently in the past, monitoring has expended virtually all funds on field collection of data and the other components of monitoring have been neglected.

7.1.2.9 Employing "outside" expertise

Include epidemiologists and population biologists in developing the research agendas

There should be a science team to advise the FWS on how to make, and keep, the monitoring efforts scientifically credible, and to help adaptively manage monitoring efforts to be most efficacious. This team would also help in prioritization of monitoring efforts.

There should be external peer review by an independent panel of experts that would periodically review the monitoring program and the science advice given.

The monitoring program should include an outside panel of expert analysts to evaluate and recommend how data should be collected and used. The DTRPAC and outside experts agreed that a monitoring program is not useful unless it has a centralized organization, which can provide USFWS with information needed to make informed decision. The centralized program should be rigorous and formal wherein agencies, counties, and municipalities contribute to a centralized fund from which integrated monitoring projects can be funded which adhere to priorities and approaches consensuses on monitoring approaches, data standards, etc.

There should be a workshop to bring experts on various kinds of monitoring and statisticians together to map a plan for developing monitoring of habitat and threats. Additionally, there should be a summit on statistical approaches to density monitoring. This summit should bring together statisticians and tortoise biologists to map out a plan for improving density monitoring.

7.1.2.10 Improving information gathering

Add health assessments to the information gathered in ecological studies and monitoring, perhaps using an existing protocol. The opportunities to collect health and genetic information as part of monitoring are huge.

Continue current serological surveys for *M. agassizzi*, adding screening for THV. Develop surveys for other *Mycoplasma* species as assays become available.

Continue necropsies (the sample currently includes 74 individuals according to E.R. Jacobson) if a rationale for these necropsies can be developed in relation to the potential for information from them to affect new knowledge and management. Data on habitat and threats should be collected as part of tortoise density monitoring so as to extend the scope of density analyses.

Monitoring should be pitched to detect change at different scales or levels of integration

Transect sampling should be refined to collect considerably more data. Additional data could include habitat measures such as rainfall, vegetation, etc. as well as measures on tortoises such as blood samples for assessing stress, health, etc.

A health, or physiological status, index needs to be developed from bodily condition measurements of individual tortoises. The condition index of Nagy may not be reliable insofar as that index can be biased by amount of water in the bladder which can amount to nearly 50% of body mass

7.1.2.11 Improving information dissemination/access

Inform researchers about both the qualities and the shortcomings of diagnostic tests (see Brown et al. 2002); for example, that clinical signs of URTD may be non-specific or specific host responses to agents other than mycoplasmas, that seropositive (ELISA) individuals may display no overt clinical signs of URTD, and that ELISA alone often is not sufficient, largely because they indicate only past exposure, and not necessarily current infection

Inform researchers about the value of different diagnostic tests in addressing different goals (see Brown et al. 2002); for example, different tests are appropriate for health assessment of an individual tortoise, for a population survey, for long term population monitoring, and for investigation of a mortality event.

Ensure that all important information is made accessible to researchers.

There should be imposed inter-agency coordination to acquire all necessary data for analyses.

Data must exist, be accessible, and be explicitly summarized for the conservation/ management plan to be scientifically credible;

Include an explicit acknowledgment describing what data are <u>not</u> available to allow a more accurate assessment of uncertainty and risk in the planning process;

Information/data should be maintained in an accessible, centralized location, and monitoring data should be made accessible to other scientists and managers.

7.1.3 The importance of interdisciplinary, cooperative, and coordinated research

The interaction between environmental scientists and environmental managers often has been contentious, even though the ultimate goal of both groups is environmental protection (Cullen 1990; Dewberry and Pringle 1994; Shrader-Frechette and McCoy 1994a, b). Many factors, such as under-use of the reductionist approach by managers (Romesburg 1991), over-use of the reductionist approach by scientists (Miller 1993), perceived irrelevance of science to the environmental problem-solving process (Johannes 1998), and lack of consistency among scientists (Kaiser 2000b), may have contributed to this contentiousness. Despite the barriers between scientists and managers, which still are not easily overcome (Kaiser 2000a), cooperation between the two groups can return important dividends in dealing with species recovery (Ecological Society of America 1995, Hyman and Wernstedt 1995, Kleiman and Mallinson 1998, Badalamenti et al. 2000).

Cooperation among scientists in different disciplines, like cooperation between scientists and managers, is likely to return important dividends in dealing with species recovery, yet such cooperation also is not easily fostered (Metzger and Zare 1999). Dealing with disease threats is an aspect of species recovery for which cooperative research would seem, potentially, to be particularly productive (Nicastri et al. 2001, Wallace 2001). Conservation efforts often could be improved markedly by involving wildlife health professionals (Kock 1996, Deem et al. 2001) and disease control efforts often could be improved markedly by involving ecologists (Hoffman 2002, Wasserburg et al. 2002, Kazura and Bockarie 2003). The potential role for ecologists in dealing with disease threats is critical as we increasingly come to appreciate the ways in which local (e.g., Ross 2002) and global (e.g., Chan et al. 1999) environments influence disease transmission and prevalence, and, in turn, we come to appreciate the role of environmental improvement in mitigating the consequences of disease (e.g., Woodroffe 1999).

7.1.3.1 Interdisciplinary, long-term research on URTD

Researchers consisting of experts on mycoplasmas (Mary Brown, PhD, University of Florida (UF); Paul Klein, PhD, UF; Lori Wendland, DVM, UF; Dan Brown, PhD, UF), gopher tortoise ecology (Earl D. McCoy, PhD, University of South Florida (USF); Henry R. Mushinsky, PhD, USF; Joan Berish, MS, Florida Fish and Wildlife Conservation Commission (FFWCC)) and population modeling (Madan Oli, PhD, UF) are working cooperatively to fill in important gaps in our knowledge about the effects of respiratory mycoplasmal infection and URTD on the gopher tortoise. The cooperative research is funded by the joint NIH/NSF Ecology of Infectious Diseases Program for five years. The premise underlying the research is that URTD is a complex, multi-factorial disease, interacting in some circumstances with other stressors to affect tortoises (Fig. **7.1).** Questions that the research is addressing include: (1) do natural and anthropogenically-induced population characteristics influence disease transmission and prevalence; does habitat quality influence disease transmission and prevalence; does the disease negatively influence population demographics; and do mycoplasmas vary in virulence, and, if so, does the strain present influence disease transmission and prevalence?

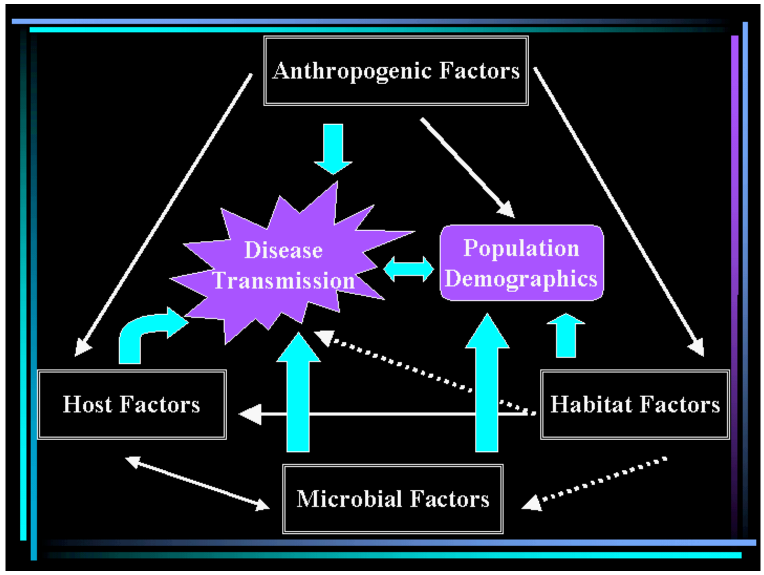


Fig. 7.1 Relationships among factors contributing to disease important to demography of the desert tortoise.

Anthropogenic, habitat, host, and microbial factors all potentially affect the interaction between URTD and tortoise populations (Fig. 7.1). Anthropogenic factors include translocation of tortoises, surrounding urban development, fire suppression, and human predation. Means of studying anthropogenic factors include field surveys, fire history data, FFWCC translocation records, and current and historic aerial photographs. Habitat factors include size, fragmentation, management, and rainfall. Means of studying habitat factors are much the same as for anthropogenic factors. Host factors include size class, sex, health status, and serological status. Means of studying host factors include tortoise surveys, ELISA, CBC, chemistry panels, and physical examinations. Microbial factors include virulence, species, and strain. Means of studying microbial factors include culturing, PCR, molecular epidemiology, and infection studies.

The data derived from the studies listed above will be used to develop causal and predictive models of the interaction between URTD and tortoise populations. The models elucidate the effects of URTD on population demographics (survival, reproduction, migration) and on population growth. The models also will evaluate the role of the major factors listed above in influencing URTD transmission and prevalence.

7.2 Desert Tortoise Science Team

The DTRPAC review leads strongly to the opinion that FWS needs to implement a Desert Tortoise Recovery Office made up of scientist, a recovery coordinator, GIS specialist, database specialist, and support staff. Some part of that staff can be outsourced to contractors, and that may be desirable. However, the FWS has had ahistory of failure on implementing recovery because the effort is not commensurate with the magnitude of the task. This species is more complex in terms of needs for recovery as any of the widest-ranging listed species in the US such as Northern Spotted Owl, Red-cockated woodpecker, Grizzley bear, etc. Thus, unlessextinction is an acceptable option, FWS must devote more resources to recovery efforts.

The Desert Tortoise Recovery Office (DTRO) should directly responsible for concerted range-wide recovery efforts for desert tortoises, It would provide a focus to cause management of desert tortoises to be more efficient and effective. The proposed Desert Tortoise Recovery Office (DTRO) would provide a centralized point of contact, through which research, data compilation, and monitoring activities are coordinated, so as to maintain the highest level of knowledge about progress toward recovery of the desert tortoise. In addition, the office would focus on identifying where new research and management should be focused to facilitate range-wide recovery of this species. The DTRO would consist of a Recovery Team leader, and a staff of specialized personnel charged with coordinating monitoring, research, Section 7 consultation, and HCP issues. The office would also have the capability of GIS analysis of data, and data storage, compilation and synthesis, as well as public relations and staff support. As a core set of responsibilities the office would:

- **Advise**, conduct, direct, and prioritize research where appropriate. Develop new techniques for monitoring desert tortoises, their habitat, and threats.
- **Synthesize** and evaluate **Research** to meet needs of management and policy. Develop a centralized desert tortoise data repository and management system and seek to standardize techniques and methods for data collection.
- Create a **Point of contact** for stakeholders groups, agencies, NGO's, Congress, GAO, etc. to address policy information needs.
- **Inform** policy through recovery recommendations and plan reviews as directed.
- **Make recommendations** for management actions based upon the best available science.
- **Address Needs** of agencies, local governments, MOG, MOG/TAC, DMG and other appropriate management organizations.

7.2.1 Science Advisory Committee

The DTRO would draw upon the expertise of a science advisory committee (SAC) in order to benefit from the most current knowledge and information available. The SAC would be composed of appointed members from the USFWS, USGS-BRD, and academia, and the Science Leader of the Desert Tortoise Recovery Office. The SAC would meet periodically to provide scientific expertise and recommendations to the DTRO.

The core set of tasks that would be covered by the SAC would include:

- Synthesize data, assess the efficacy of monitoring and prescribe needed research
- Assess progress on recovery
- Prioritize research-based recovery actions
- Consult outside scientific experts
- Rank importance of threats and networks of threats

7.2.2 Examples of problems that could be addressed by the SAC

7.2.2.1 Monitoring

There are likely to be regional differences in population trends associated with local environmental conditions, and threats to tortoises. In addition, the area of useable tortoise habitat is being reduced in many areas as habit degradation, and development continue to occur in and around DWMA's. Density estimation currently suffers from a lack of both accuracy and precision, resulting in highly variable density estimates. In addition, due to low numbers of animals encountered on transects, many transects must be pooled to get a single estimate. Thus, density estimates are currently applicable to large areas. This makes the determination of local trends in population impossible currently.

Key areas related to monitoring include:

- Assess area-specific trends in the species (density and absolute numbers of animals)
- Assess area-specific changes in quality and quantity of habitat
- Assess area-specific trends in threats and habitat loss and/or fragmentation
- Increase the precision and accuracy of density estimates

7.2.2.1.1 Data

Data are needed for the FWS to track the progress of recovery and to track the implementation of the recovery plan. Recovery and implementation require data at a scale allowing the tracking of the progress of recovery range wide, and identifying gaps in the implementation of the recovery plan. The identification of gaps in implementation will enable the FWS to prioritize management decisions, and aid the Science advisory committee in prioritizing research.

Key areas related to data include:

- Develop relational database of research pertaining to requirements as specified in the recovery plan

- Maintain (range-wide) monitoring database
- Gather and keep all data on tortoise research and monitoring
- Create and maintain GIS coverages of data

A complete description of data management, including problems in the current efforts and solutions for the future is given in the section below.

7.2.2.1.2 Research

Threats to desert tortoise populations may be different in severity in different parts of the tortoise range. Additionally there may be threats upon which management may have very little impact. Ranking of threats by severity as well as manageability should enable us to prioritize research toward the alleviation threats.

Examples of research that could be important to further our understanding of this species include;

- Learn more about age-dependent mortality of neonates
- Examine importance of predation by wild and feral predators
- How important is disease?
- Are there factors that influence the prevalence of disease?
- What can be done about threats due to disease?
  Responses of populations to habitat edges?
- How is fragmented habitat used, and is it harmful to tortoise populations?
- How are corridors used, or avoided?
- What is the importance of roads to mortality and quantitatively how can the harmful effects of roads be mitigated?
- Do tortoises use culverts, and what characteristics of culverts make them
- What makes fencing effective?
- Develop better monitoring techniques
- Research the relative importance of threats

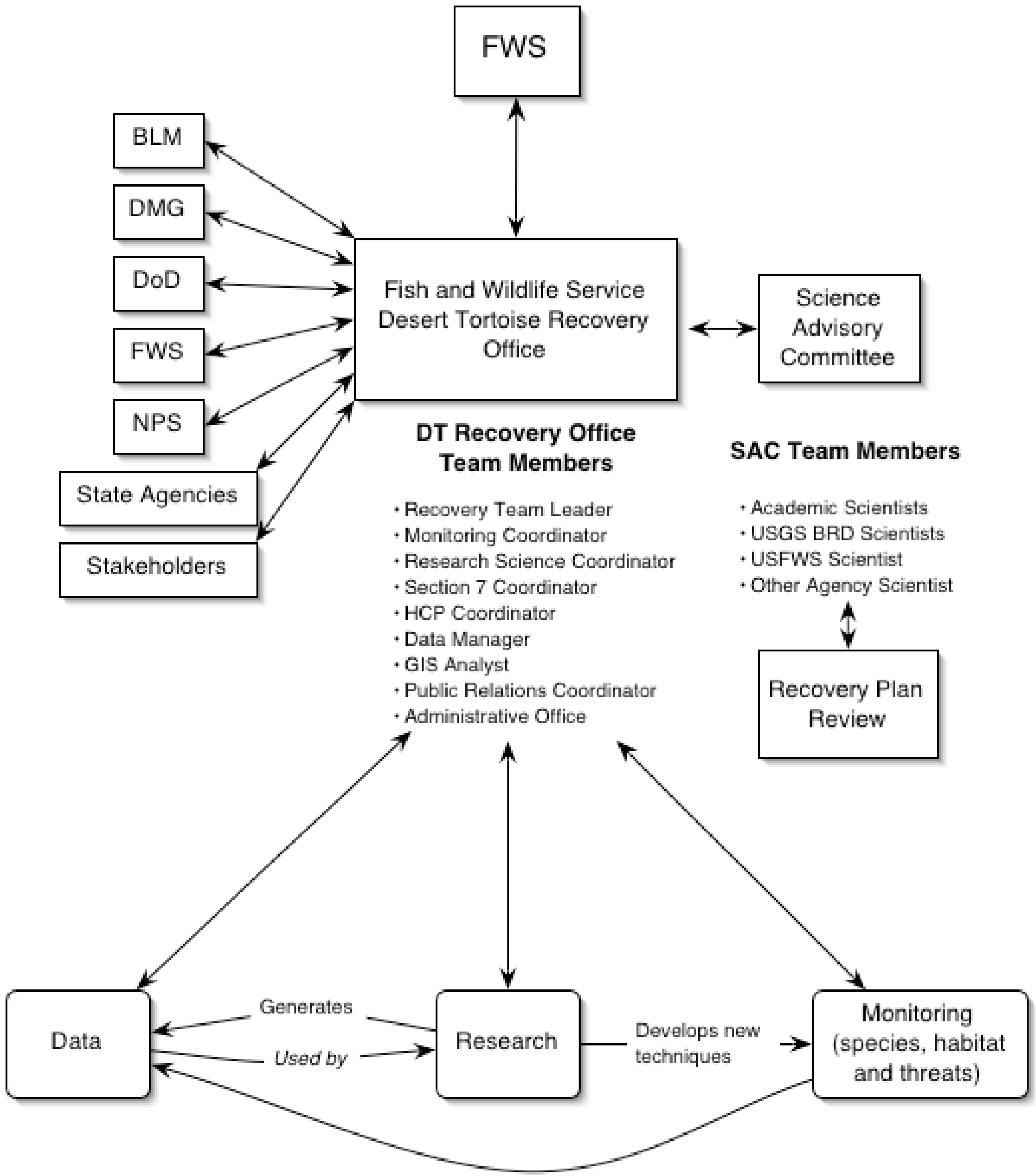


Fig. 7.2 Relationships among offices, teams, committees, etc. functioning to produce strategies for recovery and implementation of the listed species.

7.2.2.2 *Management of Monitoring Data*

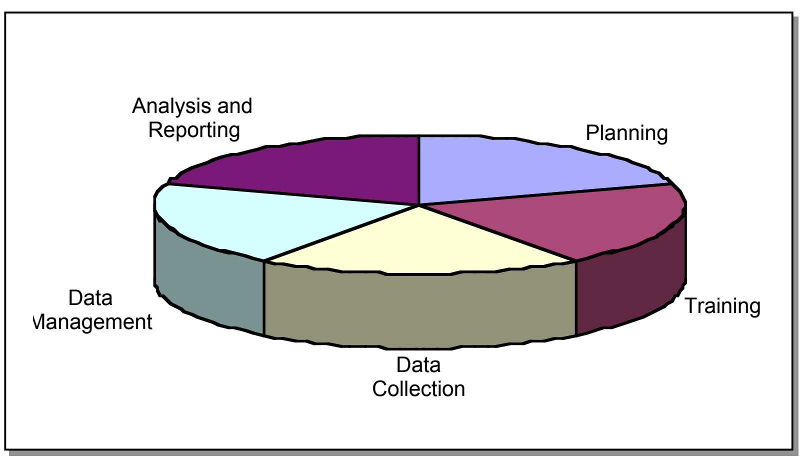
Currently, important data from monitoring tortoise densitiesare widely scattered among state and federal agencies and the scientific community. Data have been gathered, organized, and stored in a variety of ways with no common approach. Meta-data may or may not be available. Some data have been reviewed, collated, or otherwise organized. Other data have not. Accessibility of tortoise data to managers, scientists, and the public is highly variable. In short, a great deal of important data (both historical and recent data) cannot be readily used and may be at risk to being lost permanently unless the data are compiled, organized, stored, and accessible along with necessary meta-data. Successful monitoring and research programs that can support recovery of the desert tortoise will require the following:

1. Insure that monitoring funds are divided appropriately between: planning, training, data collection, data management, and analysis and reporting.
2. Developing a Desert Tortoise Monitoring Data Management Plan
3. Developing a Desert Tortoise Recovery Office made up minimally of a recovery coordinator, scientist, GIS specialist, database specialist, and support staff. Among other things, this office would insure that #1 and #2 above were implemented.

7.2.2.2.1 *Distribution of Monitoring Resources*

Data management is centrally important to data oversight, but it must be done in the context of a coordinated monitoring/research program that systematically seeks to identify monitoring/research needs, generate hypotheses, design studies, collect data, conduct analyses and report findings (i.e. scientific method). Translating the scientific method into on-the-ground monitoring/research activities requires funding to support the following activities: planning, training, data collection, data management, analysis and reporting (Fig. 7.3). Size of the pie slices is not intended to represent amount of funding needed, but to represent that each slice is as equally important as any other slice.

Fig. 7.3 Kinds of activities associated with monitoring.



The failure to devote funding, or devote only cursory funding, to planning, training, data management, and analysis and reporting and instead devote nearly all of the funds to data collection for Distance **Sampling has contributed to an uncoordinated and poorly implemented population monitoring program.**

7.2.2.2.2 Monitoring Data Management Plan

It is important to identify issues and potential solutions for improving the management of data collected for programs that monitor desert tortoise (DT) populations, threats and habitat. Data management issues and recommendations identified in this section were derived through a literature review including the EPA Data Quality System, and experience with data from tortoise density monitoring for the years 2001-2003.

Creation of a data management plan includes:

- Guidelines to standardize data collection models and management based upon data collection needs
- Guidelines to standardize and manage field data collection operations and methods
- A Data Quality Assurance Plan (that specifies required procedures and identifies appropriate manual and automated methodologies for post-processing validation and quality assessment)
- A Data Administration Plan (that identifies how verified and validated monitoring program data should be consolidated and managed in a central data repository and the identification of responsible parties).

7.2.2.2.3 Glossary of terms for data management

Below is standard terminology invoked in discussing data management that must be incorporated into DT Monitoring Program data management needs.:

Data verification – the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements.

Data validation – a …(*study*-)…specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set. (As defined by the EPA, (Citation) *data validation* is concerned with determining the utility of data once it has been *verified*).

Quality assurance – an integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the customer. (For this document, the process is DT Monitoring Program, and the customer is the USFWS).

Quality control – the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated needs established by the customer; operational techniques and activities that are used to fulfill needs for quality.

7.2.2.2.4 Error Classification

DT Monitoring data may exhibit attribute value error and spatial error. For the purposes of this document, error classification includes detection of:

Blunders (mistakes in instrument reading, data entry; erroneous computation, careless observation and recording)

Systematic Errors (a regular error introduced by instruments, measurement conditions or data processing techniques)

Random Errors (resulting from accidental or unknown combinations of cause)

The following summarizes typical sources and types of errors. Examples of such errors found in distance sampling data are provide in Appendix X.

7.2.2.2.4.1 Spatial Reference Errors

Effective analysis of desert tortoise recovery requires that monitoring program studies collect the location of field data (e.g. transects, tortoise observations). Locational data must have a spatial reference (the coordinate system, datum and projection in which location coordinates are captured and recorded). Any meaningful spatial analysis of field data requires that disparate data (collected at different times, with different equipment, by different researchers, for different contracts/projects) be converted into a common spatial reference system prior to analytical processing. An example spatial reference system, adopted by ??? is UTM (i.e. coordinate system), NAD83 (i.e. datum) and Geographic (i.e. projection). Without a spatial reference standard for DT Monitoring Program data, systematic error will occur during coordinate conversion (error in transforming raw field data during processing to unify it into a common database). Blunder and random errors, which are more difficult to detect and correct for are also possible.

7.2.2.2.4.2 Positional Accuracy Errors

Even with a standard reference system, it is possible for field researchers to capture and record erroneous locations for observations. Errors may be blunders (mistaken reading or recording by field crew), systematic (e.g. improper GPS Setup; incorrect datum, incorrect time/correction configuration) or random (unknown cause; illogical spatial locations; bad coordinate values, etc.)

7.2.2.2.4.3 Attribute Accuracy Errors

As data about a location or observation is collected and processed, errors can occur in the *values* of attribute data. These types of errors are commonly introduced during manual data entry or transcription from field sheets into a database (blunders and random mistakes in data entry/processing). These errors are the most common type, they are difficult to find, and their detection and correction is critical to producing valid data.

7.2.2.2.4.4 Incomplete Data

Incomplete data errors occur when required fields are not populated. This condition is common with manual field data capture and with digital capture systems that do not validate and enforce data entry completeness. Missing data that is required for an analysis invalidates the subject record and any records that are dependent upon or related to the incomplete record.

7.2.2.2.4.5 Inconsistent Data

Field data collection should occur using a predefined data model. There are various types of data collection instrument (e.g. paper data sheet, digital data sheet, or software application data-entry form). Data collection methods and models should predefine the data type, the data precision, and the acceptable values for each attribute (i.e. domain). Data types specify the format of a value (i.e. text, integer, decimal) and the precision (e.g. number of decimal places) that data values must have. A domain may predefine a range of acceptable values (e.g. distance > 0m AND < 30m) or may predefine a set of acceptable values (e.g. observation = ‘LIVE’ OR ‘CARCASS’).

Data inconsistency errors occur when data entry deviates from the valid data type, precision, or domain. These errors (wrong type, wrong precision, erroneous interpretation or use of predefined attribute values) can be systematic, random, or blunders. Systematic errors may be introduced during data processing that does not preserve data type and precision (e.g. an import or conversion that rounds values or reformats data types). Data inconsistency is an especially difficult problem when valid field values are used improperly. Data inconsistency can occur because (1) data collection methods, contractors and database schema change throughout the life of the monitoring project, (2) individual contractors and data collectors interpret record and process data differently, and/or (3) individual contractors and data collectors may have different understandings of the purpose, intended content and methodology for data collection.

7.2.2.2.4.6 Relational Integrity Errors

In normalized databases with more than one table, records in one table often have relationships (based on primary/foreign keys) to records in other tables. Errors occur when foreign key values reference primary key values that do not exist (incomplete data), or reference invalid primary key values (inconsistent data).

Random errors (manual data entry of the wrong/non-existent identifier for the related record) and systematic errors (reference identifier insufficient to establish unique reference [could apply to more than one record) or invalid number of references [e.g. only 4/5 of required corners]) are possible. Relational integrity errors for a single record cascade to invalidate all subsequent analysis based on the use of related data records.

7.2.2.2.4.7 Lineage and Metadata

Improper data management can lead to error. This occurs because of improper documentation of study-level data (i.e. metadata) or tracking data processing (i.e. lineage). Typical errors of the blunder, systematic, and random type include inaccurate or missing field logs, table names, interim processing file names, lack of standard methods, lost or missing logs, etc. Lost, missing or invalid metadata and the history of the data processing (i.e. lineage) can cause the entire investment in data collection and processing to be worthless for subsequent scientific analysis.

7.2.2.2.4.8 Error Detection and Correction

The most effective means to achieve a quality database is to prevent errors from occurring in the first place at each level of the workflow process. Prevention will require a combination of initiatives at each stage of data management to standardize data capture methods, to standardize the data storage model, and to standardize and automate data processing. The principal steps in the DT Monitoring Program data processing workflow are:

- Data model and database desing
- Field data collection
- Post-process raw data
- Verify post-processed data files
- Statistically validate post-processes data files
- Compile verified and validated data into a common database

The EPA's guidelines for quality assessment recommend a multi-step approach that includes two key areas - Data Verification and Data Validation. Verification is about ensuring that the data complies with the projects contract and specifications for methods and procedures. Once data has been verified, it undergoes a more analytical validation process ensure that the data is of a quality appropriate to its intended use. Data validation steps include:

- Evaluate the field records for consistency
- Review quality control information.
- Summarize deviations and determine impact on data quality

- Summarize samples collected.
- Prepare field data validation report.

The EPA suggests a Data Quality Assessment (DQA) Life Cycle that includes two essential steps for data management:

Preliminary Data Review: Review QA reports, calculate basic statistics, and generate graphs of the data. Review data structure and identify patterns, relationships, or potential anomalies (inaccurate data, missing data, etc). The EPA identifies numerous techniques for data review such as base statistical analysis (relative standing, central tendency, dispersion, association) and graphs (histograms, ranks, quantiles, normal probability, temporal and spatial distributions, etc.)

Statistical Testing: Perform the calculations required for the statistical test and document the inferences drawn as a result of these calculations. The EPA provides detailed guidance for the appropriate data analysis techniques for various study types (tests for single populations, tests for comparing populations, test for distributional assumptions, tests for trends, tests for outliers, tests for dispersions, techniques for transformation, tests for independence, etc.)

Detection and correction techniques that may be applied for each of the error types identified in DT Monitoring Program data are:

- **Standardize Database.** All data should be collected to a database template to standardize table names, attribute names and data types. In addition, this should be a geospatial database so that on-the-fly verification of GPS locations can be conducted. Using a standard data template will greatly facilitate unification of raw field data for post-processing and analysis.

- **Automated Validation in Field Computing.** Capturing all data electronically should enable automated error validation. Study area features and tortoise observation locations should be captured with calibrated GPS units that are integrated with a field/hand-help computing devices running software that can validate all data entry (and spatial coordinates) on-the-fly. The data logging device should validate all data input by data type and data value range. The data collection device and software (data entry form application) should provide standard attribute values (e.g. pick lists) and ensure that required fields are complete. The data collection software should enforce referential integrity on key relationships among study features and observations.

- **Spatial Validation.** By using in-field computing devices capable of integrating data capture with a GIS software program (e.g. ArcPad) or post-processing data could be pre-configured to validate study feature and observation locations.

- **Validation in Post Processing.** Once data is verified and validated in the field, a variety of automated post-processing techniques may be applied. This stage of processing would be designed to run database-wide checks and generate the statistical reports and graphs recommended for EPA's the Preliminary Data Review. These quality control techniques could be conducted daily as each verified and field-validated dataset is generated.

- **Statistical Validation.** Once post processing is complete and field data is delivered to the USFWS or their designated contractor, an independent round of quality control should occur. All previous stages of data processing should be re-checked and any errors should be resolved. Dataset metadata should be generated and archived along with the dataset.

- **Compilation to Master Data Repository.** Once data has passed all stages in the QC program, it should be certified and posted to a central repository to facilitate the scientific analysis, modeling and mapping for which it was designed and collected.

7.2.2.2.4 Conclusion

The current approach to data for recovery of the desert tortoise has been rife with errors and problems of coordination among the elements in the string of persons collecting and using the data. All data collection operations for desert tortoise Monitoring can, nevertheless, be designed and conducted to prevent data entry errors and to automate the detection and correction of errors during processing. Improving desert tortoise Monitoring Program data management requires a thorough review of monitoring project data collection initiatives and the preparation of a desert tortoise Data Management Plan. Once the Plan is in place, USFWS would use it to design, evaluate and manage future desert tortoise monitoring.

7.2.2.2.5 References

Principles of Error Theory and Cartographic Applications; reprinted June, 1968; United States Air Force, Aeronautical Chart and Information Center.

Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8); November 2002; United States Environmental Protection Agency, Office of Environmental Information.

Guidance for Data Quality Assessment: Practical Methods for Data Analysis (EPA QA/G-9; QA00 UPDATE; EPA/600/R-96/084); July 2000; United States Environmental Protection Agency, Office of Environmental Information.

Table 7.1 Summary of sources and types of error that have been found in the distance sampling data for desert tortoise.

Error Type	Data Tables (ATTRIBUTES)	Error	Potential Source
Positional Accuracy and Spatial Reference	Corner Coordinate, Observation (EASTING, NORTHING, LATITUDE, LONGITUDE)	Illogical spatial locations Different projects, datums and correction factors by area, by year, by contractor	▪ field crew data entry ▪ GPS Setup (Incorrect Datum, Incorrect Time, Incorrect Projection) ▪ GPS Data Error (bad coordinate values, etc.) ▪ Coordinate conversion (error in transforming raw field data during processing to unify into a common database)
Attribute Accuracy	All tables and fields.	Incorrect data values	▪ PenDragon scripts ▪ field crew data entry ▪ incorrect PDA Time
Completeness	All tables and fields. All attributes without automated validation.	Missing data values	▪ Data not validated during data entry
Consistency	All tables and fields.	Non-standard values. Example: Live and Carcass each have three different spellings in the database. Technically 'LIVE', 'live', and 'Live' all mean a "live tortoises". Attributes are not within tolerances (acceptable parameters) e.g., an MCL value of 900mm.	▪ Data entry ▪ Data collection methods, contractors and database schema changed each year. ▪ Contractors/data collectors interpret record and process data differently.
Relational Integrity (error in key relationship among records across tables)	Transect and Corner Coordinate	Transect records do not have all related (corresponding) corner coordinate records Corner coordinate record does not have corresponding transect record (Corner coordinate record has incorrect TRANSECT_Y value)	▪ Field crew does not create all corner coordinate records ▪ TRANSECT_Y value was edited.
	Transect and Observation	Observation record does not have corresponding transect record (Observation record has incorrect TRANSECT_Y value)	▪ TRANSECT_Y value was edited.
Data Type and Precision	Observation DISTANCE_M	Invalid data type (e.g. decimal numerical value is stored as an integer)	▪ Database design is incorrect. ▪ Data processing did not preserve data types (e.g. import or conversion resulted in rounded values)
Lineage and Metadata	Study-level tracking	Inaccurate or missing field logs, table names, interim processing file names	▪ Lack of convention ▪ Lost or missing logs

A. Appendix A

A.1 Cultural Background for Recovery Planning

A.1.1 The Problem

United States citizens have consistently demonstrated their appreciation for the natural resources of their nation, manifesting their respect for both beauty and societal value of wildness and wildlife resources. The public has acted to protect these resources though our national, state and municipal park systems, through agencies like the USGS, USDF, BLM, USGS, EPA, their state and regional counterparts, and through a century–old tradition of laws and statues. Nonetheless, the dominant language, English, and culture of our society with its foundations so strongly developed out of western and northern European traditions, biases our awareness in favor of forests, wetlands, and other "productive" habitats. These were landforms of superior value as sources of game and timber, and they formed the watersheds that nurtured the European societies from which so many Americans were drawn. Deserts were not part of the northern and western European experience, except perhaps when they were encountered only as obstacles in the paths of the crusaders, marching to protect the "holy lands" from "infidels". Otherwise, our imagery could be reconstructed almost exclusively from biblical accounts.

From these limited experiences, often distorted by second hand accounts, English Speakers, both British and American, came to view deserts literally as "places deserted", wildernesses inhospitable to humans by virtue of the lack of water, shelter, and arable land. From the Oxford Universal Dictionary (1955. p.489) we find this definition:

1. An uninhabited Place and uncultivated tract of county; a wilderness; now especially a desolate and barren region, waterless and treeless, with but scant herbage…
2. unpeopled, desolate, lonely

Notice that the Anglo-Saxon desert is defined entirely in negative terms. As a result, it would seem hard for public use to make deserts much worse than they are now- barren desolate, unpopulated, with few natural resources. Furthermore, it would seem logical the organisms surviving in such deserts should tolerate extreme and impoverished conditions. From this perspective a poacher, or OHV, raven, or disease might kill a desert tortoise outright, but little else could harm such an armored dweller of such an already harsh environment. If a desert user doesn't kill tortoises outright, how could his use damage an already "barren" habitat in which tortoises have traditionally thrived? This logic makes more difficult the task of helping Americans understand about the degradation of desert habitats, and how subtle and chronic processes may profoundly influence rates of tortoise morbidity and mortality. Given the public perception of deserts, how could general land uses cause "desertification" of a pre-existing desert to the point where its ecosystems destabilize, and its ability to sustain tortoise populations be compromised or abolished.

Twentieth Century science, and science education, especially nature films and television have done more to reinforce the negative perceptions than to correct them. In particular, the Adaptationist Programme (Gould and Lewontin, 1979), in its broadest evolutionary and ecological manifestations has re-enforced the following misperceptions of nature:

1. Evolution only works on through natural selection
2. All phenotype features on an organism are evolved for an adaptive function
3. All species are adapted to their current environments
4. Ecosystems made of up of these well-adapted organisms function as tightly coevolved systems in their environments, in which each component, producer and consumer, prey and predator, host and pathogen, and biogeochemical cycles interact with one another in stabilizing and compatible ways producing a “balance in nature.”
5. Finally, these co-evolved ecosystems respond to disturbance in highly predictable patterns of recovery and stabilization (often referred to as secondary succession). These responses are composed of a series of successional stages of predictable composition, duration, transition, and sequence. And, they terminate in a secondary but stable “climax” community.

These views of the natural world have been re-enforced in the eyes of American movie and television viewers of Disney’s “Living Desert” of the 1950’s forward to the “Crocodile Hunter” presentations in contemporary television. Yet, when such myths are combined with biblical and medieval views of the deserts, the public is nearly compelled to see deserts as both impoverished and perfectly adapted systems. In this view, biological communities will simply bounce back in a predictable fashion after a disturbance has past. Such ecosystems already thrive at the limits of environmental deprivation, and they are intrinsically equipped by their adaptations to recover from any natural disturbance.

When such misperceptions are broadly accepted as fact, it will be difficult to convince the lay public that subtle changes to desert landscapes, such as drought (Duda et al., 1999; Peterson, 1994, 1996a, and 1996b), fire (Brooks and Esque, 2002), overgrazing (Avery, 1998; ________ and Neibergs, 1997) invasions of alien plants (D’Antonio and Vitousek, 1992;Maack, 1981, Oftedal et al., 2002), subsidized predation, road proliferation (Hoff and Marlow, 2002), and soil alteration by OHVs (Jennings, 1997), dropping water tables, could play a significant role in the demise of the tortoise or of the ecosystems upon which it depends.

A.1.2 Problem Resolution

The task with regard to public education is clear. Education must replace the misconceptions of the Oxford definition and the five “scientific” misperceptions iterated above with a more accurate set of characterizations of deserts and the evolution and ecology of desert organisms, tortoise populations in particular.

Deserts are not vacant or impoverished landscapes. Certainly water budgets that produce net annual deficits are characteristic of deserts, manifest in closed basin physiography, saline playas, unique soils, etc. However, these same systems have positive and unique attributes as well. Desert biota often have low metabolic rates, dormancies, seasonally constrained growth and reproductive periods, unique or specialized mechanisms for retaining or recycling water, dehydration resistant morphology (dermal protections) and protective behavior (excavating refugia, nocturnal activity peaks), etc. Many extraordinary species of cryptogams, plants and animals are confined to deserts and flourish in arid settings. However, desert precipitation can vary by more than an order of magnitude, from less than 25 mm annually to more than 250 mm. Furthermore, regional differences in the seasonality of that variable rainfall result in even more extreme variation in net precipitation to transpiration/evaporation ratios. These ratios vary from site-to-site, year-to-year, and by the seasonality of precipitation. They have enormous consequences for primary and secondary productivity, seasonal blooms of wildflowers, and upon the duration of activity periods, reproductive output and success, and upon growth and survivorship of many desert species, including tortoises. The germination of winter-spring forage plants creates an uncertain and temporally constrained temporal window for rehydration, nutrition, and dispersion for all tortoises, but especially for vulnerable juveniles (Berry and Turner, 1986, Wilson et al , 1999, and Zimmerman et al., 1994.). Even subtle shifts in soil temperatures, especially in substrates surrounding eggs, may induce skewed tortoise sex ratios (Spotila et al., 1994).

It is important to remember that deserts of moderate mean precipitation (> 80mm annually) can be further desertified (Sheridan, 1981) by damaging soils, drawing down water tables, subsidizing natural or alien predators or fostering weeds though habitat modification. Subtle, sometimes chronic, degradation of desert resources, coupled with the disruption of natural cycles, may impoverish the array of resources upon which desert species, and tortoises in particular, depend (Morafka and Berry, 2002). Thus, declines in desert tortoise populations need not always be attributed to some direct assault, poaching, disease, predation, OHV collisions, etc. The death of "thousand cuts" may be acting to degrade portions of desert tortoise habitat much more effectively than any specific single threat to individual tortoises. Integrative approaches to the protection of whole desert ecosystems must remain a priority in tortoise conservation. Re-education of an informed public should include the following points:

1. Evolution acts on presumptively "neutral" gene loci through genetic drift and other non-selective processes. As a result, not all structures and behaviors, even those under genetic control, may be assumed to be adaptive.

2. All phenotypic structures and behaviors are not necessarily under explicit one gene-one-character control. Many are shaped by diet, local weather, and individual experiences. Even those character states that are controlled by direct gene expression are often exaptations, (Gould and Vrba, 1982; Armbuster, 1987, and Bradshaw,

1988) features evolved for functions different from those for which they are used today, or even evolved by non-Darwinian processes in the past.

3. Species cannot be perfectly evolved for its environment, given the nature of evolution and the dynamics of environmental change.

4. Because species are not "perfectly' adapted to their environments, the ecosystems of which they are components are not perfectly co-evolved. In the case of North American deserts, spatial and temporal shifts have been so immense and rapid that highly-reciprocal co-evolution is highly unlikely. For example, the dominant warm desert perennial has a continuous history in most southwest landscapes of less than 25,000 years (Morafka and Berry, 2002, Spaulding, 1990, and Van Devender, 2002).

5. Successional processes in North American Desert Ecosystems are still poorly documented (but see Vasek, 1983), often contingent upon climatic regimes that may no longer exist, and vary tremendously in their rates, directions, stages, and outcomes. The existence of "climax" communities in the desert Southwest is very much in doubt (Lovich and Bainbridge, 1999), and the prediction of their future conditions uncertain (Herford, 2000).

A.1.3 Consequences of Current Misconceptions:

Without the proposed re-education, a considerable segment of the public will continue view deserts as "empty spaces", appropriate for extreme and exploitive recreation. Recent claims that sand dunes are "ideal" for OHV recreation because OHV tracks are simply "erased" by the overnight winds illustrates this misperception well. Many will continue to view desert biota as noxious weeds and vermin: cactus, nettles, scorpions, mice and snakes. The less threatening species will be dismissed as being so well adapted that further desertification would not impact them negatively.

When such views prevail, it is difficult to explain why subtle but progressive desertification, driven from anthropogenic sources, could drive the tortoise to extinction. It is the subtle processes that can impoverish diets; close the winter-spring window for optimal foraging; skew sex ratios; compromise resistance to, and recovery from, disease; intensify predation on tortoises; and stop, or redirect, the processes of ecological succession. These processes may prove decisive to tortoise survival, but they are not self evident to a public that views deserts as infernos, empty zones, and the habitats of vermin invulnerable to environmental degradation.

B. Appendix B

B.1 Why knowledge of tortoise behavior is important to desert tortoise recovery

B.1.1 Principles

Understanding desert tortoise behavior can be very important to developing means to achieve recovery. The actions of living tortoises within their habitats contribute to survival, growth, reproduction, and ultimately to population persistence.

Tortoise behavior, as it relates to recovery, consists of the cumulative actions carried out by individual tortoises. The goal is to recognize critical and generalizable behavioral patterns among tortoises. This comes from the study of individual animals under natural and experimental conditions.

The behavior of individual tortoises is the result of very complex interactions among six central factors:

1. *Genetic Make-up* - Individuals are endowed with a unique genotype that will result in future individualized responses. More importantly, natural selection and drift can result in genetically-derived behavioral differences among populations. For example: (burrowing in soil versus using caves in rocks).

2. *Developmental Conditions* - Developmental conditions can strongly influence genetic expression and subsequent behavior. For example, maternally-derived nutrients and hormones as well as environmental contaminants within the egg influence neonate performance.

3. *Physiological Traits* - The ability, and manner, by which a tortoise responds to environmental conditions, and exposure to disease, is a function of its physiological capabilities. Because physiological limits and capabilities themselves are determined by genes, development, age, sex, and past physiological events, behavioral responses of tortoises to prevailing conditions may not be predictable without detailed investigation. Furthermore, as the demography of the population shifts or as the habitat is transformed, mean physiological responses across a population may shift.

4. *Morphological Traits* - Genetic make-up, development, and past physiological events determine morphological characteristics. Morphology and behavior are deeply intertwined. Morphology biomechanically limits what behaviors can be performed. (note: foraging performance, vagility, crossing barriers, etc.)

5. *Environmental Conditions* - Generally, an animal will exhibit only a subset of its total behavioral repertoire. Behaviors often are cued by prevailing environmental conditions. Humans are introducing inordinate new cues into the Mojave

ecosystem – for example intentionally placed barrier fences along highways and changes of vegetation due to invasions of exotic weed species.

6. *Cumulative Individual Experiences* - With time, an animal accumulates a set of individual experiences that can strongly influence its behavioral response to a stimulus. For these kinds of flexible behavioral responses, older individuals will tend to express successful behavioral responses (natural selection). Although counter-intuitive, net behavioral responses within a population can be a function of demography even after controlling for differences in 1-5. If tortoise lifespan has been shortened due to human-caused mortality, tortoises that once contributed most to reproduction (mature and experienced individuals) may now be lost on a regular basis.

Behavior should be analyzed in the context of the interplay of these six effects.

Most behaviors of primary conservation and recovery importance are poorly understood or unknown at this time. Because the recovery of desert tortoise is intrinsically a demographic problem, it is valuable to take a demographic approach to tortoise behavior. Doing so illustrates the central role of behavior in the recovery of desert tortoise and identifies significant gaps in knowledge of important desert tortoise behavior.

B.1.2 Behavior of Embryos and Neonates

Post-hatch performance of young birds is increasingly linked to egg quality, which, in turn, is linked to adult female physiology and the time of egg formation. Egg size (older bird lit), nutrient endowment to the yolk (Ankney), and the endowment of maternally derived steroids (Schwabl, Vleck, wendy Reed) affect the behavior and performance of neonates following hatch. Variation in neonate tortoise performance and its relationship to maternal quality are unknown.

This seemingly obscure issue is linked to tortoise conservation and recovery in two important ways. Adult females that face poor quality foraging habitat likely will produce fewer and/or lower quality eggs. Secondly, if prevailing mortality patterns act to remove mature and experienced (i.e. high quality) females, egg quality and quantity likely will decline.

Post hatch movement and habitat selection of neonate tortoises appears to be largely unknown but likely is very critical to population dynamics. The Mojave environment is heterogeneous. It is plausible that only a small subset of the general environment is adequate for the survival and growth of neonate tortoises, then these special habitats become extremely important to conservation and recovery even though they may represent a small percentage of available habitat. Do neonate tortoises go on a random walk? Are they following cues to important habitat? Are they moving independently of one another?

A corollary to this issue is nest site selection by breeding females. Adaptively, one might predict that females will select nest sites close to suitable neonate habitat if such habitat is available and females have knowledge of it. Are females limited in nest site selection? Possible limits might be: inexperience (older may do better), territoriality, loss is quality nest sites, barriers to movement to preferred sites.

B.1.3 Behavior of Juveniles

Desert tortoises have a long juvenile period. Prolonged juvenile period in birds and mammals frequently is attributed to the need for learning as well as for time needed to grow to breeding size. Apparently, little thought has been given to the possibility that the juvenile period in tortoises has important functions other than a prolonged effort to acquire the nutrients to grow to some predetermined breeding size. (Note: in many freshwater fish like trout and sunfish, and I think in other reptiles, you get “precocial” breeders of small size under conditions of limited food and space.)

Certainly juvenile tortoises engage in a suite of behaviors central to future population dynamics. Most importantly:

B.1.3.1. Movement - The degree to which juvenile tortoises move through their environment is critically important because of its link to three crucial phenomenon.

A) Juvenile Dispersal - Dispersal determines gene-flow, the “connectedness” of populations, and the genetic signal which we attempt to decipher in evaluating populations. Without significantly better understanding of juvenile dispersal, informed recovery planning will be severely hampered.

B) Disease Transmission - It is likely that juveniles move more than adults in the process of finding a place to settle. It also is likely that juveniles encounter more tortoises than in this process than do settled adults. Hence, juveniles moving through the environment and interacting (agonistically?) with other tortoises could be a central mechanism for disease transmission. We cannot verify or discount this plausible scenario without measuring juvenile movement.

C) Information Gathering - The juvenile period can be an important period of information gathering. Presumably, juveniles learn locations of food, water, shelter, potential mates, and other critical information during the juvenile period. If juveniles necessarily wander during this period of their lives, then their vulnerability due to wandering may remain high regardless of apparent environmental conditions.

B.1.3.2. Foraging and Seeking Shelter to Promote Growth - Nutrition, water, and thermal needs differ for juveniles relative to adults. Do juveniles have special habitat needs related to this growth phase of their life? Are these habitat needs being met.

B.1.3.3. Gender Differences in Juvenile Behavior. Very little known here.

B.1.4 Behavior of Adults

Considerably more is known about adult behavior, although it remains insufficient for well-informed conservation planning. Key issues are:

Disease by behavior interplay - Disease regularly causes behavioral changes in animals (listlessness and other forms of morbidity, etc.). If disease changes behavior and detection during surveys is a function of behavior, then surveys may fail to provide accurate information.

B.1.4.1 Mating system –

- effective population size can be influenced by mating system
- genetic signatures are affected by mating systems
- mating systems can create differential vulnerability of the sexes during movements
- encounters with vehicles, barriers, or humans might be influenced by mating systems
- disease transmission might be affected by searching for mates and courtship

B.1.4.1.1 Sperm Storage – With sperm storage, following insemination adult females become temporarily independent of males for reproduction. This independence lasts for the duration of effective storage. Furthermore, if males are polygynous, then adult male survival becomes relatively less important than female survival.

B.1.4.1.2 Breeding Dispersal – especially, do females return to nest areas. Are some females “sinks” by returning to traditional sites that actually fail?

B.1.4.1.3 Circannual rhythm – Detectability, interaction with good food years

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